Veterinary Hygiene

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FOURTH EDITION

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PREFACE TO THE FOURTH EDITION

THE first edition of this book was published as long ago as 1921, being followed by the second and third editions in 1934 and 1940 respectively. The revision for these earlier editions was very largely confined to that section of the book dealing with the control of diseases in animals, whilst few material changes were made in the text of the sections dealing with water, sanitation, air and ventilation, and building construction. In the thirty or so years which have elapsed between the appearances of the first and of the present edition there have occurred considerable changes in, for instance, the design and methods of construction of buildings intended for the housing of livestock and it has for long been evident that the parts of the book connected with this and several other aspects of veterinary hygiene required somewhat drastic revision in order to bring them into line with present-day ideas and practice. There was nobody more conscious of this need than Professor Linton himself, but he having retired from active participation in veterinary teaching, felt unable to undertake the task. And so with Professor Linton's blessing it fell to one of us (N.J.S.) in 1945 to assume responsibility for the thorough revision of the book. For many reasons, the work of revision was protracted, and after the appointment of the latter to the Professorship of Veterinary Hygiene at the Royal Veterinary College it was soon evident that if publication of the new edition were not to be delayed indefinitely an active collaborator must be found. So it was that his colleague (G.A.W.) came to play a major role in revising the later sections of the book, as well as in superintending the correction of the final proofs and in compiling the index.

The aims of the fourth edition remain essentially the same as those of the previous editions, albeit with some deflection of emphasis, namely, to provide a textbook on the principles and practice of veterinary hygiene which will be useful not only to the student or practitioner in veterinary science but also to anyone interested in the promotion of animal health and production.

The general arrangement of the previous editions has again been followed. Whilst in many sections the revision of the text has necessarily been of a drastic nature, wherever practicable and appropriate we have tried to retain the main characteristics of Professor Linton's work. Since this present edition has still a well-founded title to be regarded as continuing the direct line of descent from the earlier

editions, we felt that this tribute, at least, should be paid to Professor Linton's outstanding influence on the development of veterinary hygiene ever since the publication of the first edition

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EXTRACT FROM PREFACE TO FIRST EDITION

THIS book has been written in the hope that it will be of assistance to veterinary students, veterinary practitioners, and others concerned with the well-being of animals. The requirements of those studying for the Diploma of Veterinary State Medicine have been kept in mind, and special attention has been given to certain branches of Public Health work with which they should be conversant. Other sections of veterinary science which might have been included, such as Dietetics, Zootechny and Milk Hygiene, have been omitted, as their importance merits a more detailed consideration than could be accorded in one volume. It is anticipated that they will later form additions to the Series.

R. G. LINTON

EDINBURGH, FEBRUARY, 1921

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VETERINARY HYGIENE

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SECTION I

WATER AND WATER SUPPLY

PRIMARY considerations in the keeping of domesticated livestock are that drinking water must be made available to the animals in adequate amount, and that the water must be of such quality as to promote thier health and well-being. This implies that the water must not contain toxic substances in amounts that are harmful, and also that it must be free from pathogenic micro-organisms and from the ova and larvae of intestinal parasites for which it may serve as a vehicle for their transport into the animal body.

In addition to the supply for drinking purposes, a considerable quantity of water is required for the maintenance of cleanliness in the animals themselves, and in the buildings in which they are housed. Considerable amounts of water are also necessary for the cleansing of the various utensils used in the handling of animal products. This latter aspect has a direct bearing on public health, and for this reason water supplies for dairies, creameries, abattoirs, etc., should conform to the standards demanded of public water supplies for ordinary domestic purposes. The *Milk and Dairies Regulations, 1949*, include the following provisions : "All registered premises (for the production and sale of milk) shall be provided with a supply of water suitable and sufficient for the requirements of these regulations," and "The water supply for cows shall, as far as is reasonably possible, be protected against contamination." (See Part V., Sec. 12.)

Water which is chemically and biologically pure is never found in nature, excepting possibly the water vapour of the higher air strata. Natural waters contain varying amounts of "impurities" in the form of dissolved gases, minerals, and substances of organic origin, together with greater or lesser amounts of suspended inclusions which may be either of inorganic or organic origin. The character and amount of the impurities contained in the water supply are dependent on the source from which it is drawn, on the degree of pollution to which it may have been exposed, and on the methods adopted for its storage and purification. The quality and quantity of the impurities present are the

determining factors which render a water unwholesome or prejudicial to human or animal health

All statutory undertakings for the public supply of water must by law ensure that such supplies are "pure" and "wholesome" (See *Public Health Act, England and Wales 1936* The relevant Acts for Scotland are—*Public Health (Scotland) Act, 1897*, and the *Burgh Police (Scotland) Act, 1892*) Whilst these terms have never received any precise definition, there is general agreement with regard to their interpretation 'Pure' is accepted as meaning free from turbidity, colour and from any perceptible taste and smell This indicates that the water must be completely free from suspended solid matter, whether organic or inorganic, that peat acids and iron compounds must be absent or present in only negligible amounts, and that the concentration of soluble salts must not be excessive The term "wholesome" is taken to mean "not prejudicial to health" and this implies that the water must contain no pathogenic organisms, no poisonous chemicals in amounts that will endanger health, and no substance that is capable of bringing into solution lead, zinc, or other poisonous metal with which the water must remain in contact during its storage and distribution Within the limits framed by the accepted definitions of the terms "pure" and 'wholesome," considerable variations in the composition of waters supplied by different public undertakings actually occur, and it is for this reason that no attempt has ever been made to define accurately a satisfactory supply of water in terms of chemical composition

All terrestrial waters, which of course furnish the raw material of water supplies, depend for their replenishment on the precipitation of water either in the form of rain, or as hail, snow or dew Of the total precipitation on land areas, a portion is returned to the oceans through rivers and streams, part percolates deep into the soil, while the remainder is restored to the atmosphere by evaporation and plant transpiration At any given time there is a greater or lesser amount of water stored in the soil, and although a considerable interval may elapse before some portions of this water enter the streams through underground flow, it also is returned eventually to the atmosphere by evaporation.

Rainfall in Relation to Water Supply In Great Britain the distribution of rainfall is governed by the fact that the prevailing wind is a westerly or south westerly one heavily charged with moisture Precipitation of this moisture as rain occurs most heavily in the western districts of the British Isles, particularly in those of high altitude, and there is a gradual reduction in the rainfall

across the country from west to east. Thus, for example, the average annual rainfall in central and south-east England, East Anglia and a narrow belt of country extending along the east coast of England into Scotland, lies between 20 and 30 inches, while in the West Highlands, the Lake District, Wales, and in parts of Cornwall, it may exceed 175 inches per annum. From the point of view of water supply it is interesting to note that the heaviest rainfall therefore occurs in those areas where the surface rocks are hard and impermeable, and from which on that account almost all the precipitated water is shed into streams and rivers. These areas are thus specially suitable for the location of large impounding reservoirs for supplying water to large centres of population. The lightest rainfall, on the other hand, is spread over areas where the rocks are permeable and through which the water percolates to augment the underground supply. The water of this natural subterranean store can only be tapped and raised to the surface again by the boring of wells, or through natural springs.

Generally speaking, periods of abnormally low rainfall, unless very prolonged, have but little effect on the amount of water available from large artificial storage reservoirs, or on that obtainable from wells bored deep into a water-bearing rock formation. Small, local sources of supply such as shallow wells, streams and shallow rivers, may, however, be very severely depleted under such conditions, and one of the chief problems connected with water supply in rural areas lies in the provision of water in adequate amounts during periods of drought.*

During their descent, precipitation waters may be considered to be free from solids in solution, but as soon as they reach the earth's surface their composition becomes quickly altered, soluble compounds, both organic and inorganic, being brought into solution as the water flows over, or percolates through, the surface rocks. This fact is of considerable importance since the ultimate composition of the water is determined by the chemical nature of the strata with which it comes in contact.

Geology in Relation to Water Supply. From the point of view of water supply it is useful to divide rock formations into three categories, according to their degree of permeability and porosity for water, viz. :—

    (i) Rocks that are permeable and porous, such as loose sands and gravels, loosely cemented sandstones and gritstones, and some limestones such as oolitic limestone and magnesian limestone,

    *See para. 119, *National Farm Survey of England and Wales*. Ministry of Agriculture. H.M.S.O. 1946.

(ii) Rocks that are permeable only by virtue of the joints and fissures in them, and whose porosity is low or negligible, such as most limestones, including hard chalk, and most crystalline igneous and metamorphic rocks,

(iii) Rocks that are impermeable and non porous, such as clay, shale, marl, slate, and most crystalline igneous and metamorphic rocks that are unjointed.

The distribution and the mutual relationship of these three types of rock are the principal factors concerned in the location of surface and underground waters

A consideration of the geological systems of the British Isles and their distribution, which may be found in geological maps, shows that surface topography and the nature of the rocks are closely correlated. The high mountainous tracts of Scotland, the Lake District, Wales and Cornwall are built mainly on the older palaeozoic rocks which, owing to their hard and often crystalline nature, have withstood the agents of weathering To the south and east of these tracts, and dipping generally towards the east, the younger and generally softer rocks underlie the gently undulating topography of the east and south of England These two types are divided in the north of England by rocks of intermediate age, viz the newer palaeozoic rocks, which form the Pennine Range (The older palaeozoic rocks are generally hard and impermeable, while the rocks of more recent origin tend to be softer and permeable) This distribution of rocks is responsible for the fact that in the north and west of the British Isles the water supplies are derived chiefly from natural or artificial accumulations of surface water, i e lakes or impounding reservoirs, while in the east and south of England they are derived from underground sources. In the case of the former, the rainfall over an extensive area, known as the catchment area or the gathering ground, is collected into natural or artificial reservoirs by the impounding of the streams, whilst in the latter the precipitation water infiltrates into porous and permeable rocks where it is stored, and from which it can only be tapped by means of wells or springs Collection of surface water into reservoirs requires that the rocks which outcrop over the catchment area shall be impermeable in order that rainwater may run off into the streams which feed the reservoirs The accumulation of underground water stores, on the other hand, demands a permeable surface rock to allow free downward percolation of the rainwater, and also a porous or fissured stratum below the surface to act as a natural reservoir for the water

SOURCES OF WATER SUPPLY

The sources from which it is practicable to derive water supplies for public and domestic use, and for such purposes as the watering of livestock and the cleansing of dairy utensils, etc., are :—

1. Rainwater.
2. Surface water, either upland surface water or that derived from rivers and streams.
3. Underground water from springs and wells.

Because a water has a pleasant appearance and is palatable it is not necessarily wholesome, for water may be contaminated with sewage, etc., and yet be sparkling and pleasnat to drink. Waters have been classified according to their palatability and wholesomeness by the Rivers Pollution Commissioners as follows :—

Wholesome .	{ Spring water . . . . }	Very palatable
	{ Deep-well water . . }	
	{ Upland surface water . }	
Suspicious .	{ Stored rain water . . }	Moderately palatable
	{ Water from cultivated land }	
Dangerous .	{ River water . . . }	Palatable
	{ Shallow-well water . . }	

This classification must be applied with due regard to modifying circumstances, and must not be taken too literally. Upland surface water though usually pure may, on occasion, be badly polluted, and shallow springs may yield water as dangerous as that from shallow wells. The classification indicates generally what may and what may not be regarded as wholesome.

RAINWATER

The water vapour as it condenses in the higher atmospheric layers to form cloud or rain contains no dissolved chemical impurities, but during its passage from the upper to the lower air strata the water takes up oxygen, nitrogen and carbon dioxide. Rain falling over country districts may contain few other impurities than dissolved gases, but over industrial centres it becomes grossly contaminated with suspended impurities in the form of soot and dust, and also absorbs ammonia fumes and volatile acids, such as hydrochloric and sulphurous acids. Owing to its freedom from dissolved mineral matter, rainwater has an insipid taste, and is not on this account so palatable as water

that has percolated into the soil and has come in contact with soluble-minerals

Because of the presence of free CO_2 in rainwater and the consequant solvent action it has on lead, rainwater should not be distributed in lead pipes or stored in lead cisterns   If intended for drinking and other domestic purposes, rainwater is best stored underground in cement-concrete or similar reservoirs   Where it is to be used merely as an auxiliary supply, e g , for washing purposes, it may be stored in a well-galvanised iron tank above ground

SURFACE WATER

Surface water is rain that has fallen on the earth, washed its surface, and has not yet penetrated sufficiently deep to rid itself of such impurities as it may have gathered   The character of such a water will vary with the nature of the ground on which it has fallen   In country district not greatly polluted by animals or people, it will be comparatively free from contamination other than that of vegetable origin and such mineral matter as it may dissolve   An excessive amount of vegetable matter may, however, be deleterious, and water lying on a peat soil often becomes acid   Some surface waters, though quite wholesome, may have a disagreeable colour, which is derived from the vegetable matter   Surface water that may have been in contact with human or animal excreta may be dangerous, and water from the surface of arable land should not be considered fit for drinking purposes until it has been purified

Water supplies from surface water are derived either from brooks, rivers or streams, or from natural or artificial lakes which are usually situated in upland moorland districts

Brooks, Streams and Rivers are collections of water that have run on the earth's surface, together with water that has percolated to a certain depth and has again come to the surface as springs   The higher reaches of a river are its purest part since much of the water added to it as it increases in volume is contaminated surface water and is often waste water of an objectionable nature from factories, etc   It must not be thought that a clear-looking stream running through the country is pure and safe—the reverse is often the case, as it is the common custom in villages for the inhabitants to discharge their soil water directly into the stream. On no account, therefore, should water intended for human drinking purposes or for the washing of dairy utensils be taken direct from a river or stream without it first being submitted to a proper purification process

If a river were sufficiently long and was only polluted at or near

its source it would rid itself of organic impurities by the aeration that takes place during its course. Most rivers in this country receive land-washings from agricultural land, whilst some are grossly polluted by the discharge of sewage effluents; in few cases, if any, is there a sufficent interval between the various points of discharge along the river course to permit of complete purification by natural agencies. Since a great proportion of the public water supplies of England and Wales is derived from rivers, strict control must therefore be exercised by the River Conservancy Boards over all effluents discharged into rivers above the intake of a water supply. That water from polluted rivers can be rendered safe for drinking purposes by appropriate treatment, however, is instanced by the London supply, about 60 per cent. of which comes from the River Thames.

Much attention is being paid at the present time to the increasing pollution of the rivers and streams of this country resulting from the discharge of trade wastes and of effluents from sewage works. There are many instances of poisoning in livestock arising from the drinking of water contaminated by trade and industrial wastes. Fish life has also been destroyed, and the problem of drawing water supplies from rivers subject to this latter kind of pollution is becoming increasingly difficult.

The chemical character of river water is subject to wide variation according to the nature of the gathering grounds off which its feeders flow, and also to the different geological formations through which the river-bed passes. Dissolved solids taken up in one area may be later deposited in another. Thus the character of the water in a river of any length varies not only with the individual river but also in the different sections along the same river.

Upland Surface Water. The water supplies of many large towns in Britain are derived from upland surface waters, which are collected usually at some considerable distance from the towns where they are to be used, and to which they are conveyed by many miles of pipes from the storage reservoirs. The latter are situated in upland moorland areas, and may be either natural lakes or artificial reservoirs, which have been constructed for the purpose of impounding the water flowing off the adjoining hills. The chief upland water resources which have been developed by means of impounding schemes for the supply of water to large towns or cities are situated in Scotland, Wales, and in north-west and south-west England.

Natural surface accumulations of water occur where the land surface is covered with an impermeable rock and the physical contours of the ground are such that the flow of a stream or river is

directed into a natural basin   Such accumulations vary in size from large lakes whose stores of water may be utilised for the supply of large centres of population as, for example, the waters of Loch Katrine and neighbouring lochs which supply the city of Glasgow, to small ponds which frequently form the only sources of water supply for livestock, and sometimes also for the human population, in rural localities

The main feature of an artificial impounding reservoir is a dam built across a valley so that the drainage outflow from the surrounding watershed is trapped in the valley   The object of any impounding scheme is thus to collect and store the surface water shed off the surrounding hills which form the gathering grounds or catchment area   Where possible, it is customary for the authority responsible for the scheme to acquire the whole of the gathering ground with a view to preventing drainage from farm buildings and dwelling houses or the land washings of manured fields from polluting the sources of water supply   Afforestation can also play an important part in the protection of watersheds and gathering grounds by limiting the human and livestock population of the area   In addition, forest litter and humus not only absorb and hold rainwater, but furnish a protective coating which keeps the surface soil in a condition favourable to water absorption, the effect of which is to make for a more constant water feed to the reservoir than where the land is bare or has relatively little vegetation   A forest cover also reduces surface evaporation by amounts up to 50 per cent , thus making more water available for collection into the reservoir

Upland water as it flows into the collecting reservoirs may be more or less contaminated according to the condition of the ground it has washed   If the gathering area is not heavily manured, nor polluted by human excreta, the organic matter present in the water will be mainly of vegetable origin   Having entered the reservoir, the organic matter settles to the bottom during the storage of the water therein, and carries down with it a large proportion of the bacteria and other forms of plant life which are inevitably present in natural waters. Whilst most upland waters are usually considerably less polluted than river waters   they must nevertheless be subjected to purification processes before they can be considered fit sources of supply for any large urban community

The majority of upland surface waters are soft and acid, and contain very little dissolved mineral matter   Nearly all the mountain and moorland streams of Scotland Wales the Lake District and, to a lesser degree, those of Lancashire, Yorkshire, Derbyshire and Cornwall, contain a soft, peaty acidified water   On the other hand, the

streams of the Midlands and of the east and southern counties of England, with gathering grounds of chalky boulder clay, often contain water which is quite as hard as some of the deep underground waters. In the utilization as sources of supply, the soft and acid waters of upland areas present special problems, particularly the solution of lead (plumbo-solvency) which, when present in relatively large amount in drinking water, is toxic to man and animals.

UNDERGROUND WATER

It is customary to recognise two categories of water present in the soil below the earth's surface, *viz.*, "subsoil" and "deep."

Subsoil Water is held above the first impermeable stratum ; the level of this water, or "plane of saturation," rises and falls according to the season of the year and the rainfall, being normally highest in February and March and lowest in October and November. In addition, subsoil water is always moving slowly towards its natural outlet, either in springs, rivers or the sea, the actual direction of flow depending on the dip of the strata. During its movement through the soil, the water gathers a variable amount of impurities, both inorganic and organic. Any subsoil water lying near the surface is especially liable to contamination by organic pollution which has entered from the surface ; this may be of a harmless nature or may contain the excretal products from man and animals. The fitness of any subsoil water as a source of supply, therefore, must always be regarded with suspicion until the water has been submitted to bacteriological examination.

Deep Ground Water is water which lies below at least one impervious stratum. Deep underground water supplies are usually free from significant bacterial contamination, provided always that in the raising of such supplies they are not secondarily exposed to organic pollution at or near the surface of the wells or springs. Apart from this latter contingency, the bacterial population of deep waters will depend partly on whether the water was subjected to surface or sub-soil pollution before it penetrated downwards, and partly on the nature of its subterranean course. If, for instance, polluted water travels downward by soaking through permeable strata it will gradually be purified by the natural filter action of these strata. If, on the other hand, this water follows the course of cracks and fissures in the rock formations, its bacterial content may remain comparatively high.

Methods of Obtaining Underground Water Supplies.   Water supplies beneath the land surface are tapped artificially by wells and boreholes, and naturally by springs

Well and Boreholes.   Wells and boreholes are shafts or tubes sunk through the earth's crust for greater or lesser distances
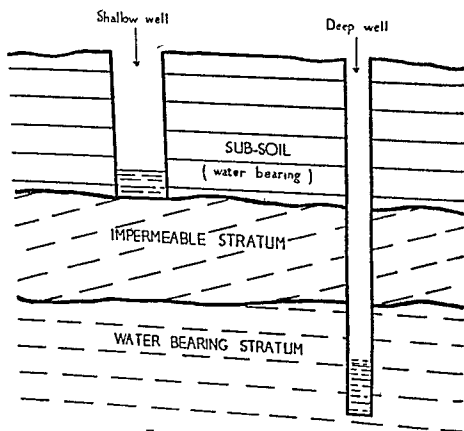
FIG 1—Shallow and Deep Wells

Three types of well are recognised, based on the geological strata they penetrate, viz , —

(i)   SHALLOW WELLS which penetrate only into the superficial strata and tap water accumulations which lie above the first impermeable substratum, the term "shallow" gives no indication of the depth of the well

(ii)   DEEP WELLS which penetrate beyond the first impermeable substratum into a water-bearing formation beneath and

(iii)   ARTESIAN WELLS which supply water at ground level from a deep underground source, the water being raised to the surface under its own hydrostatic pressure.

Types (i) and (ii) are depicted diagrammatically in Fig. 1.

Two methods for the sinking of wells in country districts are practised, namely (a) by digging out the well shaft, and (b) the driven tube method. The *dug well* is the more commonly met with, and is especially suited to locations where the flow of water in the strata is low. Such a well, usually about 4 ft. to 6 ft. in diameter, besides acting as a reservoir, provides a large surface area for the slow seepage of water. The *driven tube well*, or "Abyssinian" well, is suitable only for locations having a water-bearing gravel subsoil where the water is within suction lift of the surface—in practice less than 20 ft. This well is constructed by driving 5 ft. lengths of steel tube, 2 in. in diameter, directly into the ground to a depth necessary

to pierce the water-bearing strata. To facilitate driving, the first or bottom length of tube is fitted with a steel "point," the maximum diameter of which is slightly greater than the connecting screwed sockets on the tubes. The first length should be drilled to allow the inflow of water, and where the water-bearing medium is sandy in character, the drilled part should be covered with perforated brass to act as strainer. Where the hydro-geological conditions are suitable the driven tube well is preferable to the dug well, as it precludes to a large extent the possibility of contamination from surface water. If the working water level is more than 20 ft. below the ground surface, then
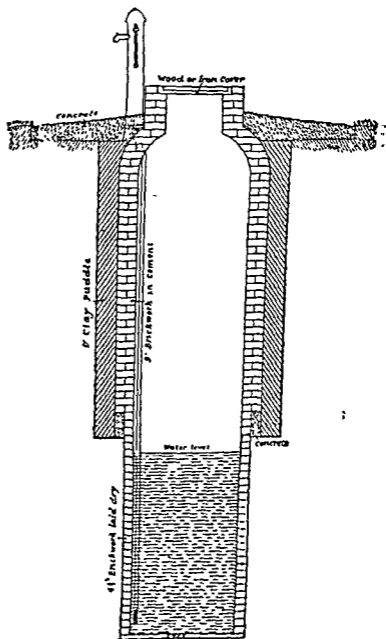
Fig. 2.—Showing a correct method of constructing a Shallow Well (Thresh).

recourse must be had to a third method of well-sinking, namely that known as the *borehole*. In this, the hole or shaft is excavated by means of suitable drills, by which impermeable strata may readily be traversed to tap water-bearing strata at depths up to 1,000 ft. or more. The hole is then lined with steel tubes or casings, its diameter must not be less than 6 in. in order to allow of the insertion and proper operation of the special pumping equipment necessary.

Great care should be exercised in choosing the site of a dug well in relation to buildings, farmyard and other possible sources of contamination. Pollution may take place either during the flow through the strata, especially in wells of the shallow type, or by direct entry into the well itself. Dug wells should be so constructed that water can only enter them from near the bottom of their shafts. This is secured by making the shafts watertight for some part of their depth with an impervious lining which will arrest the percolation of water through the sides of the well, and so lessen the possibility of pollution from unfiltered, or relatively unfiltered, surface waters (see Fig. 2). This lining, which is known as "steining," is carried to such a depth that the filtering action of the superficial strata ensures freedom from contamination in the water entering the well below that particular depth. Normally this depth will be from 6 to 12 feet, depending on the porosity of the soil. If a pump is used for raising the water from the well, this should not be situated immediately over the well shaft but at a short distance to one side. The pump is connected to the well shaft by a bent suction pipe which, after passing through a watertight joint in the lining of the well, passes vertically downwards to the water. The top of the well should be raised 6 to 12 inches above the level of the surrounding ground surface, and should be fitted with a watertight cover.

A satisfactory means of making a watertight lining or steining to a well shaft is by the use of bricks which are faced with cement. Another method is to line the shaft with large concrete sewer-pipes grouted in cement or clay. Many of the old wells met with in country districts have only a rough lining of open jointed brick or stone-work, which permits water to drain into the well from the top of the shaft and through the upper part of its sides, thus giving rise to the possibility of pollution entering through surface or inadequately filtered water. A well of this kind can be rendered satisfactory as a source of supply by lining the shaft with the large concrete sewer pipes mentioned above.

Some form of pump is usually employed for raising water from the bottom of the well shaft to the surface. The depth from which water may be raised by the ordinary type of suction pump is limited

to the ability of atmospheric pressure to support a column of water in a vacuum. It can be calculated that 32 feet is the theoretical maximum depth from which a suction pump may be expected to raise water, but in practice the distance is considerably less than this. It may be taken that the limit is 26 feet, and that if the water lies at a depth greater than this below the surface, a suction-and-lift pump should therefore be fixed in the well-shaft preferably within 20 feet of the water so as to meet any possible lowering of water level; a delivery pipe is then taken from the pump to the required point of discharge.

For the pumping of water supplies from a well in quantities such as are usually required on a farm, some form of power-driven pump is desirable, if much labour is to be avoided. There are two types of power pump commonly employed for this purpose, the positive displacement type, where the plunger operates in a cylinder, and the centrifugal type, where pressure or "head" is generated by rapidly moving propellors. Where current is cheap, an electrically driven pump has several advantages over pumps driven by low-power, stationary internal combustion engines ; the latter, in addition to the cost of fuel and repairs, involve the diversion of labour to stopping and starting them, although they are otherwise quite satisfactory. Where electric power is available, on the other hand, a float-controlled switch can be fitted which can be set to automatically control the quantity of water pumped at any one time, in accordance with the inflow into the well and the capacity of the storage tank.

In the pumping of water from a well by power-motivated pumps, it is essential to first gauge the rate and amount of delivery from the pump in relation to the inflow of the well and to the quantity of water held in the well. Care must be taken never to over-pump, particularly with wells in sandy or other loose formations, for if the water is lowered beyond a certain depth there may be an inflow of sand or silt which will choke the pump and give rise to considerable trouble. The safety level can only be found by close observation of any particular well.

Springs. Springs are natural outlets of underground water at the surface of the earth. They are encountered wherever an impervious substratum underlying a water-bearing formation outcrops at the surface. Various types of spring are distinguished according to the nature of the geological formations producing them, and according to whether their water flow is continuous or intermittent.

A spring may result from a dip in the land cutting across an impermeable stratum, which thus appearing at the surface affords an outlet to the water that has gathered above it. Such water is essentially

surface or ground water   It may be pure if the configuration of the
land is such that a considerable depth of soil covers the stratum that
holds the water   If, however, the soil is shallow, the water will appear
at the spring without having undergone sufficient filtration and may
therefore be impure   These "land springs," or "dip springs' as they
are commonly called, fail in periods of drought and "break' again
after rain and hence are often termed INTERMITTENT   If they soon
run dry and soon break then they are shallow, and the water is of
doubtful purity   If, on the contrary, the flow continues during dry
weather, then the supply is a deep one, and such springs are termed
PERMANENT

Springs also appear from a fissure occurring in a stratum such as
rock, thus letting the water underlying the rock escape   These are
called "fissure springs"   The water is pure and similar to that obtained
from deep wells   Fissure springs are not liable to fluctuation like land
springs   Another form of spring results from a geological "fault."
A "fault" occurs where two strata of different formations join with
a fissure at the junction   The water of a "junction spring" as it is
called, issues at the fissure, and may have come from a distance or be
merely surface water   Its character therefore depends upon the nature
of the ground

IMPURITIES AND INCLUSIONS OF NATURAL WATERS

*(By "impurities" are meant various dissolved constituents
which may be present in natural waters, e g , gases, minerals,
and organic substances   The term, therefore, as used in this
connection does not imply that all or any of the impurities in
solution are necessarily harmful to people or animals drinking
a water which contains them*

*The term "inclusion" is here used to signify any particulate
matter, whether inorganic or organic, which is not in solution
in the water)*

Water which is chemically pure is composed solely of hydrogen
and oxygen in the proportion of 2 to 1 parts by volume (i e , H_2O),
or 1 to 8 parts by weight   It is a clear, transparent, odourless and
practically tasteless fluid, which is colourless in small quantities but
having a slight bluish tinge when viewed in depth

Water has a very marked solvent action on a large variety of
substances , it dissolves all the commoner gases, and acts upon most
solid substances in time, the dissolved CO_2 present in natural waters
assisting in this latter process   The remarkable solvent properties of
water are responsible for the fact that chemically pure water does not

exist outside the laboratory, and also largely for the characteristic chemical qualities of different natural waters. The minerals dissolved in natural waters depend entirely upon the geological composition and the solubility of the strata over, or through, which the water has flowed. In general, too, it may be said that the amount of dissolved inorganic solids increases with the depth to which the water has percolated downwards into the earth. Hard crystalline rocks, whatever their chemical composition, are generally very insoluble, and waters shed from these rocks tend to be very low in dissolved mineral matter. Surface accumulations of water derived from such rocks, as for example in the Scottish Highlands, the Lake District, and Wales, contain almost no chemical impurities, the dissolved solid content rarely exceeding 5 parts per 100,000. The newer and softer rocks are much more soluble, so that underground accumulations which have percolated through these strata contain a high content of dissolved solids.

The substances, whether dissolved or in the form of solids, met with in natural, untreated waters may be conveniently classified as *inorganic* and *organic*. The commoner inorganic constituents include the bicarbonates of calcium and magnesium, the sulphates, chlorides, and nitrates of calcium, magnesium and sodium, and sodium carbonate. The organic impurities are chiefly humic acids derived from acid surface soils and accumulations of acid peat, but which, especially in the case of pond and river waters, may also comprise inclusions of plant and animal life and their decomposition products.

INORGANIC IMPURITIES

Calcium, Magnesium and Sodium Salts. The inorganic substances, with the exception of sodium carbonate, which may be present in natural waters are dissolved directly from the rocks through which the water has percolated. The calcium and magnesium salts, which are soap-destroying, give rise to "hardness in water." Untreated natural waters likely to prove suitable as sources of supply rarely contain more than the equivalent of 25 parts of calcium carbonate per 100,000. Certain geological formations, notably the Keuper Marl and the Oolites, contain considerable quantities of the soluble salts of calcium, magnesium, and sodium, and give rise to waters which may contain 400, or more, parts of dissolved solids per 100,000. These waters, which possess a pronounced brackish taste and are unsuitable for general supply purposes, are often used as spa waters in certain regions.

Sodium carbonate is a constituent of some Essex waters and is introduced through a base-exchange reaction which occurs between calcium and magnesium salts held in solution in the water and naturally occurring sodium zeolites which are present in some of the

strata with which the water comes into contact   This reaction gives
rise to replacement of the calcium and magnesium in the water by
sodium which then appears in solution as sodium carbonate or sodium
sulphate   Base-exchange of this kind constitutes a natural water-
softening process which is chemically identical with the artificial
process involving the use of "permutit"

Iron. Many underground waters contain iron, but fortunately it
usually occurs in such minute quantities that its presence can be
ignored Waters from some Coal Measures, sandstones, and the
Greensands may contain appreciable amounts of ferrous bicarbonate
in solution and are known as *chalybeate* waters. Oxidation of the
ferrous bicarbonate by atmospheric oxygen to insoluble hydrated ferric
oxide produces the characteristic red deposit which is invariably to be
found along the courses of chalybeate streams   This oxidation reaction
can be represented by the following equation

$$4Fe(HCO_3)_2 + 2H_2O + O_2 = 2Fe_2O_3, 3H_2O + 8CO_2$$
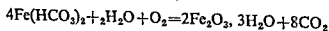
The ferrous bicarbonate imparts a characteristic, and not unpleasant,
iron flavour to the water, but it is an objectionable constituent in that
it encourages the growth of the so-called "Iron Bacteria" and thus
leads to the incrustation of pipes and the blocking of water mains
Steps are generally taken to eliminate iron from public water supplies,
usually by some form of aeration, if it exceeds 0.05 parts per 100,000.
(See also "Lime-Soda Process of Softening Water," page 24)

‡ *Fluorine.* Of other inorganic impurities which may be present in
natural waters, fluorine, because of its significance in relation to human
and animal health, has received considerable attention   Fluorides are
common minor constituents of most underground waters, but in
supplies for drinking purposes they should not be present in quantities
exceeding the equivalent of one part of fluorine per million   According
to Suckling,* "the strata which most commonly yield water con-
taining significant amounts of fluorine are the Lower London Tertiary
Beds where these are covered by London Clay.   Such conditions pertain
at Maldon and other parts of Essex. . . ."

Fluorine is now regarded as an element of high potential toxicity, and
although very small quantities are essential for the normal calcification of teeth,
the continuous ingestion of water containing fluorine in concentrations greater
than one part per million causes interference with calcification giving rise to
dental dystrophy known as "mottled teeth"   Other clinical symptoms of chronic
fluorine poisoning which have been described in the human subject include obstinate
constipation and various skin affections.

Mottling of the enamel of the teeth has been reported to be common in

*See *The Examination of Waters and Water Supplies*, by E V Suckling, 5th edit.,
1943, p 575

certain areas in both North and South America, where the drinking water contains relatively large quantities of fluorine. Thus in districts in the Argentine, where the water contains approximately 10 parts fluorine per million, a high incidence of dental abnormality in human beings and in horses has been described, and while the molars of cattle in these areas appeared to be sound, they are said to show histological lesions similar to those associated with the macroscopic mottling seen in the other species.

In addition to the presence in underground waters of fluorine dissolved from the rocks, the element may also gain access to water following local volcanic eruptions, in which case contamination is due to volcanic dust, or in the neighbourhood of certain chemical industries contamination by effluents containing fluorine may take place. In Iceland* a disease of sheep associated with exostoses of the bones and mottling of the teeth has been known since at least 1100 A.D., and which has generally appeared in high incidence after the periodic volcanic eruptions that have been a feature of the history of that Island. The malady known as "darmous" which occurs among human beings, horses, cattle and sheep in certain areas of North Africa has also been shown to be due to the fluorine which is contained in the large rock phosphate deposits found in this region. Besides the contamination of natural waters with volcanic and rock phosphate dusts in the regions just mentioned, these dusts also settle on the herbage, thus greatly increasing the fluorine intake of herbivorous animals grazing on it.

The occurrence of chronic fluorosis has frequently been reported in animals grazing in the vicinity of factories producing, for example, superphosphate, hydrofluoric acid, glazed bricks, aluminium, glass and enamel. All such factories either discharge effluents containing hydrogen fluoride or siliconfluoride into neighbouring streams, or give rise to dusts which are deposited on the surrounding pastures.

The symptoms produced in sheep and cattle as a result of chronic fluorine ingestion include difficulty of locomotion, emaciation, raggedness of coat, reduction of milk yield, and especially abnormal skeletal development manifested by swollen joints and exostoses of the long bones and jaws. The susceptibility to fluorine intoxication appears to vary with the species involved. From the published data of various authors it would seem that the approximate minimum amount of fluorine which, when ingested over a considerable period, will result in the syndrome said to be characteristic of chronic fluorosis is for the hen 70 mg., pig 10 mg., cow 3 mg., and sheep 3 mg., of fluorine per kg. body weight per day.† Amounts smaller than these which do not appear to affect general health and productivity of livestock may, nevertheless, induce dental symptoms and increase the fluorine content of the skeletal tissues.

ORGANIC IMPURITIES AND INCLUSIONS

The dissolved impurities and particulate inclusions of an organic nature which may be present in water supplies may be regarded as falling under the two headings :—(i) Chemical, and (ii) Biological. *Chemical Impurities* of organic origin present naturally in water may result either from the breakdown of organic material in the soil complex that the water has traversed, or they may arise from the death and decomposition of plant and animal life actually inhabiting the water.

Roholm, K. (1934) Arch. wiss. prakt. Tierheilk., 67, 420.

†See review article. *Chronic Fluorine Intoxication in Domestic Animals*, by Pierce, A. W. (1939). Nut. Abst. & Revs., 9, 253-261.

The presence in a water of very small amounts of nitrogenous constituents (ammonium salts, albuminoid ammonia, nitrates and nitrites) is usually due to the natural decomposition processes mentioned above, but the finding of these substances in relatively great concentrations, on the other hand, must be regarded as strong presumptive evidence indicating pollution of the water with sewage or manurial matter. The significance of the presence and the concentration of the various impurities originating from organic decomposition is discussed under the *Examination of Water Supplies* (See pp 37f)

Biological Inclusions. All natural waters, excepting possibly some of the deepest underground waters, are inhabited by a diverse plant and animal life, the chief phyla of the former being Algae, Fungi and Bacteria, whilst the animal kingdom is represented by Protozoa, Sponges, Rotifers, Molluscs, various free-living "Worms," Insects, Fishes and Amphibia   The kinds of plants and animals found in any particular water depend largely on the character of the water and on the source from which it is drawn, and, as far as contaminant intestinal bacteria of human or animal origin are concerned, on the degree to which the water has been exposed to sewage and/or manurial pollution   In general, the flora and fauna of surface waters are more abundant and more diverse than those of underground waters, whilst those of the deepest subterranean waters are relatively poorer than the life of sub-soil waters   A few minute Crustacea feeding on bacteria and fungi are able to live in deep wells and in the subterranean waters on which they draw, but if the wells be of great depth or are poorly aerated the water will usually be devoid of living things   Few, if any, of the forms of life, apart from contaminant bacteria of intestinal origin, which may be found in natural waters would appear to be toxic or harmful to man or animals drinking the water   Their chief significance as regards water supplies is in connection with the methods of purification adopted for large public supplies, and with water storage and distribution   (For an excellent short account of the more important biological features of natural water and of the purification by biological means, reference should be made to the pamphlet, *Biology of Water Supply*, No 7A of the Economic Series, published by the Natural History Department of the British Museum)

In the following paragraphs, some account is given of the more important forms of plant and animal life which are to be found in water supplies, and which may give rise to problems during the purification, storage, and distribution of the water   Contaminant bacteria of intestinal origin which may gain access to the sources of water supply will be dealt with under the "Bacteriological Examination

of Water Supplies" (See pp. 481.) and consequently any consideration of these is omitted here.

ALGAE   The Algae constitute the most ubiquitous form of plant life existing in freshwater ; the majority are microscopic in size but some are visible to the naked eye, e g , the bright green thread-like algae often seen in ponds and streams

From the point of view of water supply, three groups of algae are of great importance, namely the Isokonatae or Green Algae, the Myxophyceae or Blue-Green Algae, and the Diatoms   These and other groups of algae, which may only flourish moderately in the comparatively still waters of lakes and storage reservoirs   This increase is useful in some ways   The aeration of the water by the algae helps to purify it and, as will be mentioned later, they play a vital role in the purification of water supplies by filtration processes but, if their growth becomes excessive, they may interfere with filtration   Such excessive increases in the algal population of open storage reservoirs can be controlled by the application to the water of a chemical algicide, such as copper sulphate which is used at the rate of 2 to 10 lbs $CuSO_4$ per 1,000,000 gallons of water   Care must be taken to ensure the even distribution of the $CuSO_4$ throughout the reservoir   The usual method of application is to tow a bag of the salt along carefully planned lines in the reservoir   It is better policy to use $CuSO_4$ as a preventive against excessive algal multiplication in a reservoir than as a curative, in which case the dead algae undergoing decomposition may render the water unfit to use for some time   Objectionable taste due to algal growths may be removed by dosing the water the with powdered activated carbon at the rate of 1 to 5 parts per million   The covering-over of small reservoirs will effectively reduce algal growth therein

A great bulk of algae passing on from storage reservoirs to the filter beds during periods of algal abundance introduces mechanical difficulties in the filtration of the water, and unless the filtration plant is frequently cleaned the filter beds will become choked   The use of algicides in the filter beds is not practicable, as the putrifaction of very large quantities of dead algae may be even more objectionable than the presence of the living plants in the water   If it is necessary to remove offensive tastes after filtration about 0 5 part per million of potassium permanganate may be used

SOIL BACTERIA   Ground-water lying near the surface will usually contain free-living bacteria derived from the upper few inches of the soil complex These bacteria include aerobic forms which break down organic material into its simple component elements of carbon, nitrogen and hydrogen   This resolution process is further carried on by two groups of nitrogen-oxidising organisms, which convert ammoniacal nitrogen to acid radicles that in combination with existing soil bases form nitrites and nitrates   The first of these bacterial groups (*Nitrosomonas*) converts ammonia to nitrites, whilst the second (*Nitrobacter*) completes the oxidation process by converting the nitrites to nitrates, which constitute the completely oxidised state of N_2 The bacteria which initiate the breakdown of organic material, as well as those involved in the oxidation of nitrogen, require for their efficient functioning the provision of adequate moisture, oxygen, suitable bases and an environmental temperature of over 5°C   Unless these requirements are satisfied, the disintegration of organic matter cannot proceed to completion and the end products represented by the humic acids now formed cause "souring" of the soil   Water draining from a soil in which these conditions pertain will be acid in character as, for example, the acid waters draining from water-logged peat accumulations, in which the incomplete breakdown of the excessive amounts of vegetable organic

matter is due to the absence of oxygen and of suitable bases The plant remains are finally converted to true peat by anaerobic bacteria Sandy soils, which are always characteristically low in mineral matter, may also under certain conditions accumulate organic matter, because in the absence of soil bases (lime) the decomposition of plant debris cannot proceed, and layers of peat may be formed Similarly, even on heavy land plant debris may tend to accumulate, e g , many old grass lands have matted turves many inches thick which show little or no signs of decomposition if ploughed in unless lime is used to correct the soil acidity Another example of failure of this biological scavenging process sometimes occurs in connection with land treatment of sewage-tank liquor, where as a result of excessive application of the sewage liquor the alkaline bases in the soil become exhausted, and consequently the conversion of the acids formed by the nitrifying bacteria to nitrates and nitrites does not occur and they accumulate in the soil, rendering it "sewage- sick " Such soil may have its purifying properties restored by the addition of 1 to 2 tons of lime per acre, combined with a period of rest from further sewage application

IRON BACTERIA Certain of the Bacteria have the power of abstracting iron from the water in which they live and of depositing it in the form of ferric hydroxide in the mucilagenous sheath with which they are invested The ' ochre-beds" sometimes seen on boggy moorland streams are produced by the deposition of the iron impregnated sheaths of these bacteria which sink to the bottom of the stream when the bacteria die The presence of iron in their surrounding medium is not essential to the life of the Iron Bacteria, for they can flourish in its absence The iron seems to be assimilated by the bacteria probably in the form of ferrous bicarbonate along with nutrient materials, is oxidised to the insoluble hydrated ferric oxide, $2Fe_2O_3 3H_2O_5$ and is then deposited in this form in the filament sheaths of the bacteria.

Crenothrix is perhaps the best known of the Iron Bacteria though possibly it is not the most widespread As normally found, it consists of minute filaments attached by one end to some solid object Each filament consists of a single row of cells, the whole being invested by mucilagenous sheath Rapid multiplication of Crenothrix in supply reservoirs has occasionally produced spectacular effects in the water drawn from the service main The last severe outbreak of this kind in a public water supply recorded in Great Britain appears to have been at Cheltenham in 1896 A number of instances in the last quarter of the nineteenth century are reported from the Continent of Europe in which the luxuriant growth of Crenothrix caused considerable trouble not only in the storage reservoirs and filtration plant but also in the distribution system The service supply pipes became coated with a rusty pile of Crenothrix, and in one of the outbreaks the pipes were actually obstructed by a hard, ferruginous deposit The water was unusable for domestic supply owing to its bad taste and smell, and in one instance (at Lille, 1872), it is recorded that horses refused to drink it.

The effect in water supply systems due to Gallionella, another of the Iron Bacteria, is less stinking than those of Crenothrix, but this organism is probably far more widespread Gallionella forms a slimy coating on the inner surface of iron supply pipes, from which streamers extend into the water , this coating may become so thick that it considerably reduces the capacity of the pipes Gallionella also plays a part in the formation of the hard rusty nodules and incrustations that are commonly seen in water-pipes in some areas The exact role of the bacteria in the production of these is uncertain, but it is thought that in some way they accelerate the deposition of rust, probably through their oxidation processes Chlorination of the water is one of the remedies that have been found

satisfactory in the control of Iron Bacteria and the troubles arising therefrom in public supply systems

FUNGI   Since all free-living fungi are saprophytic, i e derive their nourishment from decomposing organic material, the occurrence of fungi growing in water is evidence of the presence in the water in question of decomposing organic substances, and therefore of possible excretal pollution

The number of species of aquatic fungi is small, and of these the only one which needs consideration in relation to the purity of water supply is the association of fungi, bacteria and protozoa, commonly known as the "Sewage Fungus,"* which may be found in streams and rivers into which sewage effluent is discharged   The appearance presented by this growth is that of a dirty yellow or greyish jelly-like film covering the bottom and sides of the watercourse in which it occurs, and which is especially abundant where the current is slow or the watercourse tortuous   It may be found growing plentifully in drains which carry off the effluent water of sewage farms   Wherever this fungus occurs, it is a certain sign of the presence in the water of a large quantity of organic compounds and, therefore, of possible pollution either with sewage effluent, or perhaps with raw sewage

FAUNA OF WATER SUPPLIES   Members of all the chief groups of freshwater animals are to be found in one or other of the various sources from which water supplies are drawn   They may gain access to purification plants at waterworks, but rarely cause serious trouble in these   In the past, before the sand filtration of public water supplies was universally adopted, there are several instances where Sponges, Polyzoa and Mollusca are reported to have flourished abundantly in service pipes and mains   The sand filtration of water effectively excludes the minute larval stages of these animal types, which can pass readily through the strainers used to stop the grosser inclusions of natural waters   Should these larvae, on the other hand, gain access to the water pipes, they may lodge at suitable sites and develop into the adult forms   The latter feed on Diatoms and other Algae which are invariably present in unfiltered water, and may multiply so greatly as to seriously reduce the capacity of the pipes   They afford lodgment, too, to a whole host of organisms which would otherwise be swept on by the current, and when members of this pipe fauna die their decay pollutes the water and favours the growth of saprophytic sewage

The common freshwater fishes are usually to be found in sources of water supply, such as rivers and natural lakes   They are thought to exercise a beneficial influence on the quality of the water, in that they feed on the smaller plant and protozoal forms, and so possibly limit the numbers of these   For this reason, artificial impounding reservoirs for the storage of water are commonly stocked with fish, generally trout

HARDNESS OF WATER

The term "hard" describes and owes its origin to the hard or harsh feeling that is obtained when soap is rubbed up with certain waters that do not readily form a lather   The description "soft" is given to waters that form a soapy lather with ease, and which have a soft feel   Since a hard water does not readily form a lather with soap, while a soft water does, it follows that more soap will be required to

* See Butcher, R W (1932) Contribution to Our Knowledge of the Ecology of Sewage Fungus, *Trans Brit micol soc*, 17, 112

† See "*Water Softening*," Report of a Committee appointed by the Minister of Health H MSO 1949

produce a lather in a given quantity of hard water than in the same quantity of soft water, on the degree of hardness, therefore depends the soap destroying power of a water and as will be shown later, this power of a water may be used to determine its relative hardness

Hardness in water is due to the presence of calcium and magnesium salts in solution which react with soap to produce an insoluble curd or scum of calcium and magnesium soaps, it is removed, and the water rendered soft, by precipitating or otherwise removing the calcium and magnesium from solution The calcium and magnesium salts which are found most frequently in natural waters and which impart to them this property of hardness are —(a) bicarbonates and (b) sulphates and chlorides The bicarbonates are common constituents of natural waters and are introduced through the solvent action of water containing dissolved carbon dioxide on calcium and magnesium carbonates —

$$CaCO_3 + CO_2 + H_2O = Ca(HCO_3)_2$$
$$MgCO_3 + CO_2 + H_2O = Mg(HCO_3)_2$$
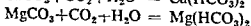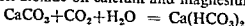
These bicarbonates are decomposed at the temperature of boiling water, carbon dioxide being evolved and the insoluble calcium and magnesium carbonates being precipitated from solution —

$$Ca(HCO_3)_2 = CaCO_3 + CO_2 + H_2O$$
$$(ppt'd)$$
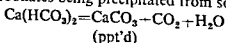
Hardness due to bicarbonates can therefore be removed by boiling and such hardness is called TEMPORARY hardness The sulphates and chlorides of calcium and magnesium are unaffected by boiling, and hardness due to their presence can only be removed by chemical treatment of the water Hardness due to these substances is called PERMANENT hardness

Waters differ greatly in degree of hardness according to the nature of the soil through which they have percolated and from which they are collected Those collected from the igneous or oldest rocks are the softest, while those from chalk and limestone are the hardest Intermediate between these two extremes are the moderately hard waters collected from the sandstones and shales The Rivers Pollution Commissioners tabulate the relative hardness of waters according to the source as follows descending from softest to hardest —

(1) Rain water, (2) upland surface water, (3) water from cultivated land, (4) river water, (5) spring water, (6) deep-well water; (7) shallow-well water Shallow wells may, however, contain soft water

Hardness in water may be estimated by determining the quantity of a standard soap solution, whose strength has been so adjusted that 1 ml of it is equivalent to 0 5 milligrams of calcium carbonate, that is required to produce a permanent lather with 50 mls of the water under examination ; the number of mls of soap solution required is

numerically equal to parts of calcium carbonate per 100,000 of water, or "degrees of hardness." Hardness is also expressed occasionally as grains of calcium carbonate per gallon or "degrees Clark"; this is a most inconvenient practice which is fortunately falling into disuse. Since one gallon of water weighs 70,000 grains, the figure expressing grains per gallon can be converted to one expressing parts per 100,000 by multiplying it by the factor 1.43 (or by multiplying it by 10 and dividing the product by 7).

The terms hard and soft have never been quantitatively defined, but a rough arbitrary scale using these terms with qualifying adjectives has come into use. The following table gives a classification according to this arbitrary scale :—

Description		Parts of CaCO₃ per 100,000	Grains of CaCO₃ per gallon
Soft	... ...	5 or less	3.5 or less
Fairly soft	...	5-10	3.5-7
Moderately hard		10-15	7-10.5
Fairly hard	...	15-20	10.5-14
Hard	... ...	20-30	14-21
Very hard	...	30 and over	21 and over

The Significance of Hard and Soft Waters. Hard or soft waters have been variously associated in the past with a number of physiological disturbances both in animals and man. Hard waters have been held responsible for goitre, the development of renal calculi, dyspepsia and other gastric disturbances in the human subject, and dry, hard coat and gastric disturbances in horses. Soft waters have been stated to reduce the rate of calcification of teeth in children, resulting in dental caries in later life. This association of physiological disturbance and the relative hardness of the drinking water has been the subject of considerable investigation in human medicine and it is now recognised that so far as general health is concerned the extent and nature of the hardness is without effect. Suckling* summarizes the present standpoint as follows :—"We have examined thousands of their reports (i.e., of Medical Officers of Health) for counties, boroughs, urban and rural districts, and we have not found in any single instance a medical officer who has reported any difference in the death or sickness rates between districts supplied with hard or soft waters."

On the other hand, hardness does affect the suitability of a water for a number of purposes other than drinking, and for which purposes preparatory chemical treatment of the water is desirable or even essential. When water is heated sufficiently to drive off the CO₂ the calcium and magnesium carbonates are precipitated, forming the "fur" in kettles and boilers. "Boiler scale" is due to the deposition of the sulphates.

*Op. cit.

converting the calcium zeolite, CaZ, back to its original condition as sodium zeolite, Na_2Z —

$$CaZ + 2NaCl = Na_2Z + CaCl_2$$

This second reaction, whereby the exhausted calcium zeolite is reconverted to sodium zeolite, is called "regeneration" The two reactions can be carried out intermittently over an almost indefinite period, the water softening zeolite known as "permutit" losing only about 1% of its activity after some 200 cycles of operation

In the zeolite system of water softening all the calcium and magnesium in hard water is replaced by sodium, so that both temporary and permanent hardness are removed in a single operation by this process The replacement of the lime and magnesia salts by an equivalent amount of sodium salts results in an increase in the alkalinity of water softened by the permutit process, and doubts were at one time expressed as to the wholesomeness of such alkaline waters Experience has now established the fact that these softened waters are perfectly wholesome, and indeed they are probably better than the hard waters from which they are derived The popular table waters such as natural "seltzer water" and "Apollinaris water" contain considerable quantities of sodium salts in solution, and are appreciably more alkaline than waters softened by a base-exchange process

In recent years the special properties of acid-treated coal and other carbonaceous materials, and of bakelite have been utilised for water treatment Besides possessing the property of base-exchange, they are also capable of acid-exchange an exchange reaction involving acid radicals, or anions By the use of these substances hard waters, or even sea water, can be brought to a purity approaching that of distilled water, and small scale plants are now frequently utilised to produce a purified water from tap water for use in chemical laboratories These plants comprise two distinct units Tap or other chemically impure waters entering the first unit have their dissolved bases replaced by hydrogen an acid water therefore being the product of this reaction —

$$CaSO_4 + H_2Z = CaZ + H_2SO_4$$

       calcium   hydrogen   calcium   sulphuric
       sulphate   zeolite   zeolite   acid
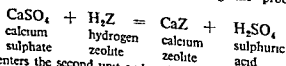
This acid water enters the second unit and undergoes an acid-exchange reaction, all acids present being replaced by carbonic acid The treated water issues with only carbonic acid as an impurity, which can be removed if necessary by aeration For regeneration of the zeolites in these units hydrochloric acid is used in the first unit and sodium carbonate in the second —

$$H_2SO_4 + ZCO_3 = H_2CO_3 + ZSO_4$$

    sulphuric   zeolite   carbonic   zeolite
    acid   carbonate   acid   sulphate
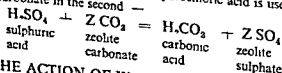
THE ACTION OF WATER ON METALS

Pure water has little or no corrosive action on metals but natural waters, by virtue of the salts ... may exert a

pronounced corrosive action   The substances present in natural waters which are responsible for this corrosion of metals may be divided into three groups —

(i) Substances which are acid in nature such as carbon dioxide and peat (i e humic) acids

(ii) Substances which are alkaline in nature such as sodium carbonate

(iii) Soluble salts, particularly the nitrates and chlorides of sodium, calcium and magnesium

The first group of substances can be said to be corrosive of all metals, but those principally affected are lead, iron and zinc, copper and bronze are affected to a lesser degree   The corrosive action of these waters on lead and zinc has received greatest consideration owing to the poisonous nature of these metals and the fact that almost all domestic supplies come into contact with them at some time during their passage from the reservoir to the consumer

Lead.   Waters exerting a corrosive action on lead are termed *plumbo-solvent*   The natural waters which are chiefly responsible are upland surface waters containing dissolved carbon dioxide and humic acids and containing little or no calcium carbonate in solution   Such waters are acid, their pH values varying from about 6 8 to 4 5 , their corrosive action increases rapidly with decreasing pH value

Since lead is a cumulative poison the maximum amount permissible in a drinking supply must necessarily be extremely small   No actual limit has been definitely fixed but it is recommended that the amount of lead present in a domestic water supply should not exceed 0 01 parts per 100,000

It is important to remember that the lead solvent power of a water is not constant but varies with a number of factors   New lead pipes are attacked by all waters, whether hard or soft, but a protective coat of insoluble basic lead carbonate rapidly forms under the influence of hard water so that the amount of lead dissolved by them diminishes with time   The acidity of upland surface waters varies with rainfall During periods of dry weather the acidity of the water held in the ground surface increases and the first rains following these dry periods displace this water into streams which become charged with water that is very acid and therefore highly plumbo solvent   The acidity of this water falls after the ground has been washed with continuous rain

The plumbo-solvent action of waters can be eliminated by treating them firstly with alum to coagulate the peat acids, and after filtration in order to remove the coagulum with lime to remove the excess of carbon dioxide acidity   The two operations are frequently carried out

which become thrown out of solution when the water is heated under pressure   The wastage of soap when hard water is the only water available for washing purposes is very great compared with what it would be if the water were moderately soft   With hard waters the waste pipes from kitchens and lavatories become coated with the insoluble stearate, palmitate and oleate salts which on decomposing make the pipes foul   Synthetic detergents are unaffected by hardness in water and no precipitation occurs when they are used

For making solutions of disinfectants, sheep-dips and for similar purposes a soft water should be used

The Treatment of Hard Water   As hard water is generally unsuitable for domestic and industrial purposes, measures are taken to remove the hardness   Temporary hardness can be removed by boiling when only small quantities of water have to be dealt with, but large quantities are treated chemically by one of the following methods —

1. Lime and Lime-Soda Softening.   The chemical procedures used in these processes aim at the removal of calcium and magnesium salts from solution by precipitation.   Calcium in solution as the bicarbonate and all salts of magnesium can be precipitated by slaked lime the slaked lime reacting with them as shown in the following equations —

$$Ca(HCO_3)_2 - Ca(OH)_2 = 2CaCO_3 + 2H_2O$$
$$Mg(HCO_3)_2 - Ca(OH)_2 = Mg(OH)_2 - 2CaCO_3 - 2H_2O$$
$$MgSO_4 - Ca(OH)_2 = Mg(OH)_2 - CaSO_4$$
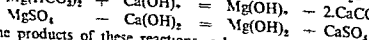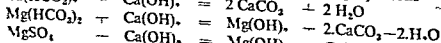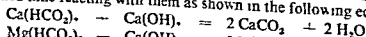
The products of these reactions, calcium carbonate and magnesium hydroxide are insoluble in water, and this treatment with slaked lime therefore results in the removal of —

(a) the temporary hardness due to calcium and
(b) all hardness due to magnesium.

These reactions form the basis of the Lime Process for softening water, but it should be noted that lime treated water still retains some permanent hardness due to the presence of salts of calcium other than the bicarbonate   These salts do not react with lime and further treatment of the water is necessary to bring about their removal   The usual chemical procedure adopted is to precipitate them as insoluble calcium carbonate by the addition of sodium carbonate in a form known commercially as "soda ash"   The reaction taking place can be represented by the equation —

$$CaSO_4 - Na_2CO_3 = CaCO_3 - Na_2SO_4$$
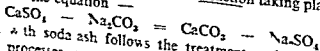
Treatment with soda ash follows the treatment with lime and the combined processes are referred to as the "Lime-Soda Process"   Water treated in this way loses all its hardness both temporary and permanent, and is left with a small quantity of sodium sulphate in

solution. In practice the quantities of lime and soda required are accurately computed following the chemical analysis of a sample of the water to be treated.

Ferruginous waters may be also freed from iron by the lime-soda process, and are usually treated in this way. The base-exchange process to be described is not suitable for ferruginous waters.

2. *Softening by Base Exchange*. Reference has already been made (p. 15) to a natural process by which calcium and magnesium salts in solution in water are converted to sodium salts by a so-called base-exchange reaction. This reaction is utilised for the large-scale softening of industrial and domestic supplies. The process relies on the characteristic property of "ion exchange" possessed by certain naturally occurring minerals such as clay and other alumino-silicate minerals, and by synthetic materials such as the artificial alumino-silicates, acid treated coal and coke, and bakelite resins ; such compounds possessing ion exchange properties are called "zeolites." The zeolite which is most widely used in water-softening plants is known as "Permutit," an alumino-silicate which may be of natural occurrence or artificially prepared.

The chemical reactions involved in ion exchange is summarised by the following equation :—

$$Ca(HCO_3)_2 + Na_2Z \rightleftharpoons CaZ + 2.NaHCO_3$$

| Calcium | Sodium | Calcium | Sodium |
| bicarbonate | zeolite | zeolite | bicarbonate |
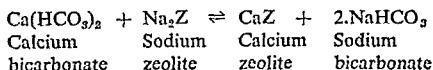
The zeolite, "Na_2Z," is an insoluble, and in use an almost indestructible, compound which removes calcium and magnesium ions from water solution, replacing them by sodium. The two directional arrow in the centre of the equation denotes the fact that the reaction is reversible, the direction in which the reaction proceeds depending on the concentrations of the reacting substances. Thus if the concentration of calcium salts in the water is high, as it is in hard water, the reaction proceeds from left to right, calcium is replaced by sodium and the water is softened. On the other hand a concentrated solution of sodium salts will cause the reverse reaction to take place and sodium will now displace calcium from the zeolite.

Both reactions are made use of in practice. The reaction from left to right proceeds during the softening of hard water, but a stage is reached when all the sodium held by the zeolite has been replaced by calcium, when further softening ceases. The zeolite is then treated with a strong solution of brine (i.e., sodium chloride) which causes the reaction to proceed now from right to left, thus

raising the oxygen content of the middle layer   The bottom of the reservoir is frequently devoid of available oxygen and is the site of anaerobic decomposition of organic materials   To avoid the removal of the tainted water from the bottom of the reservoir, and the filter-blocking algae from the surface, means are usually provided for drawing off water from the reservoir at points between these layers

Filtration. While the mere storage of water in reservoirs and service tanks considerably improves its quality and appearance, it is not in itself a sufficient safeguard when the water is to be used for domestic purposes The completion of the purifying process is done by *filtra-tion*, and in addition it is sometimes *sterilised*

All surface waters i e , those collected from a watershed and impounded, all river waters and sub-soil waters, must be considered as exposed to the risk of contamination, and therefore requiring filtration

Filtration is normally carried out by allowing the water flowing from the reservoir to percolate through sand, and two types of sand filters are recognised, slow sand filters and rapid sand filters.

The slow sand filters when first put into use act simply as strainers, removing solid matter in suspension without retaining bacteria, but after a time the sand grains become coated with a film of organisms which are effective in biologically purifying the water as it passes through the filter   Slow sand filters which have reached this condition are said to have "ripened" and such filters require careful supervision to maintain them in this ripened condition out of doors, where temperature control of the biological process they undertake is impossible   Slow sand filters function efficiently, but as they only pass about 2½ gallons per square foot per hour, they suffer from the obvious drawback that they need to be very extensive to cope with a large volume of water

In rapid sand filters the water drawn from the reservoir is forced through the filter under pressure, either by means of a pump or by maintaining a head of water above the filter   Suspended particles are removed but biological purification does not take place   Purification is effected in this case by introducing a coagulant *before filtration,* or by sterilising with chlorine afterwards

Coagulants in the form of freshly precipitated hydroxides of many metals possess the property of adsorbing considerable quantities of organic matter, and this property is made use of in removing organic contaminants from water, the metallic hydroxide in common use is aluminium hydroxide   In practice the aluminium hydroxide precipitate is formed in the water by adding to it either aluminium sulphate ("sulphate of alumina" or the pure compound "alumina ferric")

or sodium aluminate. In both cases the aluminium salt is hydrolysed to aluminium hydroxide which settles rapidly, dragging with it at the same time the organic matter dissolved or suspended in the water. Bacterial contamination is largely removed by this procedure and the removal of filter-blocking particles permits of a more rapid and efficient filtration subsequently.

Impure water when it has been filtered is improved in appearance, colour, taste and odour. Its organic matter is reduced and its bacterial content may be reduced 99 per cent. The micro-organisms that are pathogenic to man are more easily killed in the film than are the harmless ones, and coliform bacilli, which are always found in sewage, are taken as the index of the efficiency of the filtration, because if they are absent from filtered water it may rightly be presumed that pathogenic organisms are also absent.

Sand filtration keeps back from the service pipes the fauna that are found in storage reservoirs and which, if they gain entrance to the pipes and cisterns, cause much trouble and spoil the appearance of the water. The film is sometimes impaired by the burrowing of worms, small eels and sticklebacks, so that on occasion water may pass through only partially filtered. Gas bubbles, the result of animal life in the film, may leave a ruptured surface on the film when they break loose.

While the purification of water for domestic use is very important, the same precautions need scarcely be taken for farm animals or for general use on farms, were it not that impure water, when used for washing out dairy utensils, may be the means of starting an epidemic of typhoid or other water-borne disease.

If water containing much suspended solid matter, or muddy water, is habitually drunk by animals it leaves an ever-increasing deposit of silica, mica, &c., in the alimentary tract. This is a cause of colic, constipation and, in the case of mica which forms a coating on the mucous membrane, malnutrition. Water of this nature can be roughly filtered by passing it through a gravel and sand bed or, in cases of emergency, through coarse canvas.

Chemical Sterilisation of water aims at the destruction of all non-sporulating pathogenic organisms, particularly those of intestinal origin, which may be present in it.

Sterilisation of water, whether on a large or small scale, by the use of chemicals should always be preceded by some form of filtration so as to remove the grosser particles of organic matter. The chemical substance used for sterilisation must not impart a disagreeable taste to the water nor make it harmful to animals or people, while at the same time it must possess sufficient germicidal power to effect its purpose.

simultaneously by adding a mixture of alum and chalk to the water. Where such chemical treatment of potentially lead-solvent waters is difficult or impracticable, the use of lead service pipes or lead-lined storage containers must be avoided

Animals or people drinking water that has been conveyed for any distance in lead pipes, or which has been stored in lead cisterns or has stagnated for any period in lead pipes may, if the water is lead-solvent, take into their bodies minute quantities of lead   Lead, however, is cumulative, so that if water containing the merest trace of lead be habitually drunk there may come a time when toxic effects will be produced and symptoms of lead poisoning will become apparent [*]. Serious cases of lead poisoning have occurred in both animals and man, and the cause and nature of the illness has not always been suspected

An outbreak of plumbism in horses illustrative of the lead-solvent action of peat water and of the serious consequences resulting from failure to diagnose the condition is recorded by Hugh Begg [+] The water was drawn from a long circuit of lead piping early in the morning and run into a tub, thus the horses were drinking water that had been in contact with the lead through the night and before any had been run off ; it was found to contain 045 parts of lead per 100 000, while water sampled after the pipes had been running for ten minutes contained only a trace   Twenty-four horses either died or had to be destroyed

Zinc. Zinc is readily dissolved by acid waters, by alkaline waters containing dissolved sodium carbonate, and by waters containing excessive quantities of chlorides or nitrates   Few natural waters therefore can be regarded as wholly non-corrosive with regard to zinc. As enormous quantities of service pipes in use are of galvanised iron, i e, zinc-coated iron, the question of the possible toxicity of zinc assumes considerable importance   It is generally accepted that with the human subject the ingestion of small quantities of zinc results in dyspepsia, constipation, and sometimes diarrhoea, but there is some conflict of opinion as to the amounts of zinc that can be tolerated before these symptoms appear   There is no evidence to show that zinc accumulates anywhere in the body as does lead, and since it appears to be eliminated rapidly, it seems that fairly heavy doses would need to be administered to produce physiological disturbance   Suckling [++] considers 0 5 parts of zinc per 100,000 to be innocuous, but that alternative supplies should be sought if the amount exceeds this figure appreciably. Instances are on record however where waters containing as much as

* Dr Ruth Allcroft, as a result of recent work (1951) doubts whether this occurs
in animals   (Vet Rec 63, 583)

+Begg, H (1928)   J Comp Path, 41, 159

++ Op cit

3 parts per 100,000 have been consumed over prolonged periods without ill effect. It may also be noted that zinc-lined troughs are used extensively without apparently causing illness in animals.

Natural waters generally dissolve zinc as the soluble bicarbonate, but waters that are alkaline due to the presence of sodium carbonate may dissolve it as sodium zincate, and waters containing an excess of chlorides or nitrates may dissolve the zinc as the soluble chloride or nitrate, or as a soluble double salt. The amount of zinc does not generally decrease with time, which means that no protective coat forms on zinc surfaces under the influence of natural waters as it does in the case of lead. Indeed the amount brought into solution may increase with time if the zinc coat becomes eroded to an extent that exposes the iron beneath, as under such conditions galvanic action occurs which accelerates the dissolution of the zinc. The zinc-solvent action of acid waters can be reduced to negligible proportions by neutralising the acidity with chalk or magnesite. Other zinc-solvent waters are not affected by this treatment.

PURIFICATION OF WATER SUPPLIES

The methods employed for the purification of water depend upon whether the water is to be dealt with in bulk, as for public supply purposes, or in smaller quantities for a domestic or farm supply.

LARGE SCALE PURIFICATION

The statutory requirements of a "pure and wholesome" water supply are generally met by the supply of water that has been treated so as to ensure the absence of pathogenic organisms, other factors, *e.g.*, relative hardness, etc., affecting the suitability of the water having been considered and dealt with before the question of purification arises. The treatment received by public supplies at the present time may comprise one or all of the following processes :—

Storage,
Filtration with or without the aid of coagulants,
Chemical Sterilisation.

Storage. The storage of water in large open reservoirs is practised principally as a water-conservation project, but it also fulfils an important function as a water purifier. Sedimentation of suspended matter results in the removal of turbidity, and the sediment also carries down with it an appreciable quantity of organic contaminants. Exposure to sunlight, and the oxygenation of the water by respiring algae effect the removal of many pathogenic and other organisms. Although algal growth is confined to the surface layer, the oxygen introduced into the water through its agency diffuses downwards

The sterilising agents most frequently used for the treatment of potable waters are chlorine and ozone. Chlorination is more generally applicable and is cheaper than ozonisation although the latter process possesses certain advantages over the former. In both processes the essential feature is the introduction into the water of the sterilising agent in such concentration as to leave a small residuum of free agent after a contact time between agent and water of sufficient duration to ensure destruction of pathogenic bacteria

Efficient sterilisation can only be carried out in water free from suspended organic matter, since bacteria embedded in particles of organic material may not be reached by the sterilising agent. Also, organic matter reduces the efficiency of most chemical sterilising or disinfecting agents, the concentration of sterilising agent available for the destruction of bacteria being reduced rapidly to negligible proportions

Chlorination. Chlorination is essentially the addition of "free" chlorine to water, it may be introduced as chlorine gas as sodium hypochlorite or as bleaching powder Chlorine gas is used in large scale practice while sodium hypochlorite and bleaching powder find use in small scale sterilisers The two recognised procedures for the treatment of water by free chlorine are normal chlorination and super-chlorination

In *normal chlorination* the concentration of chlorine is brought to such a level that a residuum is left after a contact time between chlorine and water of at least half an hour, this contact time is extended as long as practicable It is arranged for the residuum of chlorine to be so small that it imparts no detectable smell or taste to the water, so that the water is available for use without further treatment Difficulties occasionally arise where the water before treatment contains substances that react with chlorine to yield products possessing a powerful and objectionable taste Traces of phenol compounds for example, even in concentrations as low as 1 part in 2000 millions, react with chlorine to produce chlorphenols which impart a very objectionable and persistent "iodoform like" taste and smell to the water. These difficulties may sometimes be obviated by superchlorination which results in the complete destruction by oxidation of the substances concerned, but the safest procedure appears to be the removal of such compounds before chlorination by filtering the water through charcoal.

Superchlorination is adopted where the contact time between water and sterilising agent is necessarily reduced (e g, where storage tanks

are not available or their use is inconvenient). In this process chlorine is introduced into the water to a concentration about ten times that used in normal chlorination. Rapid and complete sterilisation is effected in a few minutes, but the treated water contains a very high residuum of free chlorine and must be dechlorinated. Sulphur dioxide (in large scale practice) and sodium thiosulphate (in small scale practice) are the dechlorinating agents in general use. The advantages of superchlorination lie in the very short contact time required for sterilisation, and also in the fact that as the high concentration of chlorine tends to oxidise organic matter completely there is less tendency for taints of the chlorphenol type to develop.

Chloramine. A combination of chlorine and ammonia is now widely used for the sterilisation of water. It is less affected by the presence of organic matter and its sterilising action is more prolonged than that of chlorine. Its only other advantage over chlorine is that it does not to the same extent give rise to iodoform and chlorinous tastes in the water. Its bactericidal effect is, however, very much slower than that of chlorine and long contact is therefore necessary, which in many circumstances is a decided drawback to the use of chloramine.

OZONISATION. Ozonisation is practised in this country chiefly for the sterilisation of swimming bath water. It is generally preferable to chlorination for this purpose as no objectionable taste or smell is imparted to the water. It is of interest to note that the efficient sterilisation by ozone is due in part to the presence of impurities in the form of oxides of nitrogen which are more toxic to bacteria than is ozone itself. The wider use of ozonisation is prevented by the high initial cost of the ozone production plant and the high consumption of electric current by the plant in use.

SMALL SCALE PURIFICATION

Boiling. Except for domestic purposes or for the sterilisation of very limited amounts of water, boiling is impracticable in most circumstances. as for instance in the supply of water to a dairy farm. Boiling is, however, of great value when there is reason to believe that the filters of a public supply have become temporarily faulty or when, owing to heavy flooding, surface water has gained entrance to wells or springs. When such an accident as the latter occurs, warning is usually given by the turbid appearance of the water.

Chlorination is the best method for the routine treatment of small supplies of water, the chlorine being readily obtainable in the form of chloride of lime (bleaching powder). The latter should be added to the water in such quantity that free chlorine will be available to the extent of at least one part per million of water. This may be done by first

preparing a solution of chloride of lime consisting of 1 ounce of chloride of lime to 1 quart of water, which will suffice to treat 2,000 gallons of a water not containing an excessive amount of organic matter After chlorination, the water should be allowed to stand in an open tank for four hours before being used

In the case of waters which contain much organic matter or are heavily contaminated by bacteria, super-chlorination followed by dechlorination should be the method adopted After standing for not less than 30 minutes, small quantities of this water may be dechlorinated by adding sodium thiosulphate, which removes the taste of chlorine

Potassium Permanganate very rapidly decomposes in the presence of organic matter, yielding nascent oxygen It is a feeble disinfectant in water, but has a specific action on the cholera vibrio owing to the lethal effect of oxygen on this particular organism A better reaction is obtained by the addition to the water of some dilute acid This treatment is not used on a large scale but is sometimes adopted for the disinfection of wells and water tanks The amount of permanganate added must obviously vary with the degree of pollution Lelean* says "The treatment of wells is effected by adding to each gallon of water 60 grains of permanganate with 3 drachms of strong hydrochloric acid , leaving for twenty four hours, pumping until the water is colourless , removing dead aquatic fauna"

DISTRIBUTION AND STORAGE OF WATER SUPPLIES

In the case of large supplies for public use, the water is led from the collecting and storage reservoirs through aqueducts, which may be open or closed, to the purification works After purification treatment at the works, the water is pumped to the service reservoirs which should be covered to prevent the possibility of contamination or of algal growth Service reservoirs are situated on elevated sites, or placed in specially constructed towers, from which the water can be supplied by gravitation throughout the district first via the trunk distributing pipes or service mains' and thence by service pipes to individual premises

The materials used for the making of pipes and cisterns must have no deleterious effect upon the water carried or stored Pipes for service mains may be of cast iron, steel, asbestos cement or reinforced concrete Cast iron and steel pipes must be protected against corrosion and rusting, and one of the methods used for this purpose is to coat the pipes immediately after casting and while they are still hot by

Sanitation in War, 1919

dipping them into a bituminous solution. A lining of Portland cement approximately one-quarter of an inch in thickness is another method now adopted to give a protective coating for the interior of cast-iron water mains. Lead pipes have many practical advantages, both for service pipes and for the distribution of water inside buildings, but where the use of lead is inadvisable because of soft or acid waters, service and supply pipes should be made of galvanised (*i.e.*, coated with zinc) wrought iron.

Service and supply pipes should be laid underground at a depth sufficient to protect them against the effects of frost; this is usually at a depth of 2 feet 6 inches. They should not be laid on, or through, polluted earth, or in contact with any substance liable to have a corrosive action upon them. These pipes have frequently to be laid side by side with drains, and if their jointing is sound probably no great harm will result but wherever possible this practice should be avoided. These precautions are necessary in case of a defect arising in a water-pipe through which polluted water or air may be drawn into the service pipe should a negative pressure be produced within it, as will happen for example when the pipe is emptied. In the case of an intermittent supply (*i.e.*, where the supply is shut off for some hours each day, the pipes are alternately full and empty), negative pressure is developed in the empty pipes, so that if they are defective pollution is especially likely to arise.

Storage Cisterns. For the storage of domestic supplies, the capacity of a cistern should be not less than 25 gallons, and if it is to be used as a "free" cistern (*e.g.*, to supply a hot-water system) as well as a storage cistern for other purposes, its capacity should not be less than 50 gallons. Where possible, water for drinking purposes should be taken direct from the main and not from storage. Storage cisterns are usually made of galvanised iron, although galvanised mild steel and copper are also used. From the point of view of ensuring purity of the water, slate or glazed fireclay would be excellent materials for storage cisterns, but owing to their weight they are impracticable in buildings. It is also difficult to make satisfactory joints with slate.

The position chosen for a storage cistern should be clean, accessible, well lighted and well ventilated. The cistern should be fitted with a dust-proof cover, and be provided with an overflow pipe of appropriate size discharging into the open air. The supply pipe should be taken through the side and not over the top of the cistern, and down service connections should emerge at least two inches above the bottom to allow for sedimentation. A cistern used for the storage of drinking water should be cleaned out at intervals. Galvanised cisterns should

not be scrubbed out as this tends to remove the protective coating of zinc

SUPPLY AND STORAGE OF WATER IN RURAL AREAS FARMS, ETC

On farms and other premises in country districts not receiving a public water supply, two methods are commonly adopted for obtaining supplies from other sources, viz, (1) from a well, in which case the water may be distributed by gravitation, or, if this is not possible, a (electric motor, lower power engine) force pump, and (11) from a surface source, such as a lake, stream or spring in which case the water may be distributed by gravitation or, if this is not possible a hydraulic ram or windmill may be used to raise the supply to a height above that from which the flow of water began. The water is conveyed from its source by supply pipes to the storage cistern in the case of dwelling houses, and on farms to one or more storage tanks situated at convenient centres for distribution to cowhouses dairies etc, in or about the farm buildings and, where necessary to drinking troughs in the fields. Troughs should be of the self filling type, fitted with ball-cocks to prevent wastage of water

Where rainwater is the principal source of supply, the storage reservoir should be placed underground. If this is to be constructed in brick work, the reservoir is more easily made water tight if rectangular in plan. Good, non porous bricks are necessary and they should be set in cement mortar. The walls should be 9 inches thick, or the width of two standard bricks, all bricks being laid as "stretchers," i e, laid on their beds with their greatest dimension parallel with the face of the wall. The courses in the outer half of the wall are kept two inches higher than those in the inside, so that in this way the brickwork is "bonded horizontally as well as vertically, thereby avoiding joints in the outer half falling opposite those in the inner half of the wall. The interior surfaces should be rendered in good cement mortar. A reservoir constructed in this way is very unlikely to leak. Every precaution must be taken to prevent surface and other contamination, and the top must, therefore, be covered and provided with a sealed means of access, the top should also, if possible be finished so that it lies above the surrounding ground level. Reservoirs may also be constructed of good cement concrete or of large calibre reinforced concrete pipes such as are used for sewers, in the case of the latter the bottom is formed with concrete and finished in cement.

Cisterns for the storage of rainwater should preferably be of some non metal material, e g concrete or possibly slate. If iron is used it

must be well galvanised as rainwater has a very corrosive action on iron. *(acidic in nature)*

THE EXAMINATION OF WATER AND WATER SUPPLIES

For the purpose of deciding whether a particular water supply is suitable for domestic use, or for use in connection with the handling and processing of human foodstuffs such as milk or meat, a detailed examination of samples of the water in question must be made. This is done to ensure that water intended for these purposes has not been subjected to excretal pollution of human or animal origin, that it contains only traces of organic matter and no injurious impurities, and that mineral salts are not present in such amounts as to impart an objectionable taste to the water or render it excessively hard.

A complete examination of a water supply comprises :—

(i) A topographical examination of the source and circumstances of the supply.
(ii) A bacteriological examination of samples of the water.
(iii) A physical and chemical examination of samples, and
(iv) A microscopical examination.

The hygienic quality of a water is best determined by submitting samples to a bacteriological examination, the immediate purpose of which is to determine whether the water has been subjected to sewage or excretal pollution. The main object underlying all bacteriological examinations of water supplies is to ensure that certain specific bacteria pathogenic to man—organisms of the typhoid-paratyphoid group—are not present in the water. Direct search for these pathogenic bacteria cannot be made as a routine measure, since they usually gain access to water supplies in only very small amounts and the technical difficulties of isolating small numbers of an organism such as the typhoid bacillus from contaminated water are very great. Consequently an indirect approach to the solution of the problem has been adopted. Since organisms of the typhoid-paratyphoid group are liberated in the excreta of persons harbouring them in their intestinal tract, and having regard to the difficulties of directly demonstrating the presence of these organisms in contaminated water, it is assumed for the purpose of safeguarding water supplies for human consumption that any water which has been subjected to excretal pollution must be regarded as being *potentially* contaminated with typhoid-paratyphoid organisms, and *ipso facto*, potentially dangerous. The problem, therefore, in the bacteriological examination of water supplies now becomes one of applying methods, which must be relatively simple in their technical aspects, for the detection of sewage or excretal

pollution Experience has proved this reasoning to be sound in practice

During the last century methods were evolved for the detection of organic matter in water by chemical means, and further methods were evolved depending on the estimation of free and albuminoid ammonia, chlorine, nitrates and nitrites for distinguishing between organic matter of animal and vegetable origin In this way considerable progress was made towards the purification of water supplies but in spite of the large amount of work carried out it was found that these chemical tests were not sufficiently delicate or specific for the detection of minor degrees of sewage contamination The earlier bacteriological methods which, with the rise of bacteriology, were adopted for this purpose comprised approximate estimations of the number of bacteria capable of growing at atmospheric and at body temperatures These tests, however, had little advantage over the methods evolved by the chemists Attention was, therefore, directed to the demonstration of bacterial species, of known excretal origin, particularly organisms of the coliform group, faecal streptococci and *Clostridium welchii* Since certain types of these organisms are constantly present in the intestinal tract of man and animals, and because these types are not known to have a free living saprophytic existence, it follows that the finding of these organisms in a water supply constitutes strong evidence that recent, or comparatively recent, excretal pollution has taken place Furthermore wherever pathogenic organisms of the enteric group, i e , typhoid or paratyphoid bacilli, gain access to a water supply, they are always accompanied by the organisms naturally inhabiting the human intestine The finding of the latter therefore, indicates that the water in question is potentially, though not necessarily actually, dangerous to human beings consuming it Further consideration of this subject will be found under the bacteriological examination of water (see pp 48 f)

From what has been said above it will be seen that the tendency in the procedures for safeguarding the hygienic quality of water supply has been to pass from the cruder and less discriminating methods of chemical analysis to the more delicate and more specific bacteriological techniques The importance of the bacteriological examination has been stressed here, because there is still sometimes a tendency to lay undue emphasis on the chemical examination of water as a means of determining its hygienic quality Nevertheless, chemical analysis as a means of indicating possible pollution is still useful, particularly in the case of small rural water supplies, such as those used by an isolated dairy farm, or by a single or a few households, where the routine bacteriological examination applied to large

public supplies would be impractical. In such situations the relatively less complicated chemical examination may be adopted either as a routine check on the hygenic quality of the water, in which case it should be carried out at regular intervals, or as a preliminary step in the determination of organic pollution when this is suspected. In the latter contingency, however, the final answer can only be provided by the results of the more elaborate and time-consuming bacteriological examination.

From the animal health point of view, the chief application of chemical analysis is as a means, firstly of determining the occurrence of the normal constituents of natural waters in concentrations which may be injurious to health, and secondly of detecting the presence of unusual impurities known or presumed to be toxic, such as lead, arsenic, fluorides, cyanides, etc. In addition, certain natural waters, which are excessively hard and for which preparatory softening is desirable, are unsuitable for the solution of disinfectants and dips. The recognition of such waters is, therefore, of considerable importance for the effective and economical use of these preparations in animal disease control.

Interpretation of Water Examinatinos. The interpretation of the results obtained from an examination of a water is not as simple as the chemical or bacteriological techniques employed might suggest, and calls for considerable experience in this type of work. Each sample submitted to investigation must be judged on the sum total of knowledge obtained by the topographical and laboratory examinations considered in the light of experience of the hygiene of water supplies in general. Laboratory examinations, however complete or careful, can never take the place of a complete knowledge of the conditions at the sources of supply and throughout the collecting, distributing, and storage systems. Matters like the propinquity of possible sources of contamination, the nature of the collecting area, and possible faults or fissures in water-bearing strata constitute some of the information which must be weighed and assessed in reaching a conclusion. Such contingencies, too, as accidental cesspool leakage, casual contamination of gathering grounds, leaks in the distribution system and the effects of variations in the pressure in water mains or of temporary cessation of supply may more or less abruptly pollute a supply which had previously passed all the laboratory tests. All such information is vital to a correct interpretation of the bacteriological and chemical procedures which are used in determining the hygienic quality of water.

It must be emphasised that the laboratory examination of a water

on one occasion, or only at infrequent intervals, however favourable the results, does not justify the conclusion that the supply will never become subjected to pollution or that in the future such water will always be suitable for human consumption. The impression of security given by laboratory testing of water supplies at long intervals may, in fact, be quite false. For example, pollution of a source of supply, whether deep well, spring or stream, is especially likely to arise after a prolonged drought followed by heavy rains, and in such circumstances a check examination on the quality of the water should be carried out on one or more occasions. A water derived from wells sunk in fissured strata, such as chalk or limestone, is always liable to sudden pollution if situated in the vicinity of cesspools or other similar sources of contamination. This is especially likely to happen when the overlying collecting area is becoming built up and where increased pumping, drawing water from greater distances underground, may be required to cope with a larger demand for water; such water needs very frequent examination to ensure the detection of sudden pollution if it be serving as a source of supply for a large urban community. Upland surface sources of supply, where there is little possibility of human contamination, hardly need examination apart from that applied to the water actually distributed to the mains.

When considering the results obtained from isolated examinations of water supplies, it must always be borne in mind that the most which bacteriological or chemical tests can prove is that, at the time of examination of the sample, bacteria indicative of excretal pollution did, or did not, grow under laboratory conditions or, in the case of chemical analysis, certain inorganic or organic chemical substances were, or were not, present. A satisfactory result apart from other data does not exclude the possibility of contamination, whether of inorganic or organic origin, having occurred in the past or occurring in the future. For the safeguarding of comparatively large water supplies, it is far more important to examine numerous samples by a simple test than occasional samples by a more complicated test or series of tests. In the case of small rural supplies, any routine examination even by a simple test is obviously out of the question. In such situations, therefore, every precaution must be taken to protect the source of the water from any risk of contamination; thus, together with a few careful bacteriological and chemical examinations, should give assurance that any such supply is protected for indefinitely long periods.

TOPOGRAPHICAL EXAMINATION OF WATER SUPPLY

The mere examination of the source of a water is often in itself sufficient to condemn it without taking the matter any further. The examination of the supply and its surroundings is not, however, sufficient to pass a water as "pure and wholesome."

The observer should make it his business to note the source of supply of the water on farms with which he may be connected. It is true that fully to understand water supplies and the possibilities of their pollution a more than passing knowledge of geology is necessary. But it is also true that with but an imperfect understanding of geology one may acquire much valuable information concerning the water supplies of one's own district.

If the water is supplied from the public water works, probably all that need be done is to note its degree of hardness. If very soft and acid, as when coming from moorland, it is liable to attack lead, and if it is conveyed in lead pipes it may be well to warn users of the risk involved.

If the water is excessively hard it will probably be found that some provision has been made for the collection and storage of rain water. If this supply is drawn upon solely for domestic purposes, as for clothes washing, no attention need be paid from the veterinary point of view, but if it is used in connection with the dairy or for livestock or for the making of sheep dips or for similar purposes, then the method and place of storage should be inspected and samples taken for laboratory examination.

Rain water is sometimes stored in an underground tank to which is attached a so-called filter-bed through which the water passes before it enters the tank. This is an unsatisfactory method of storing water, as the filter rarely receives attention and soon gets foul.

The topographical examination of *surface supplies, i.e.,* water from ponds, streams, ditches and the like, is of great importance, as these sources are peculiarly liable to pollution from sewage and other objectionable matter. In country districts, drainage into a pond or ditch without any pretence at previous purification is often chosen as the easiest way of disposing of sewage.

The examination of the source of supply should not be limited to the immediate locality from where the water is drawn. It may be necessary to trace back a stream or ditch when pollution is suspected in order to detect the cause of the *trouble, if such exists.*

Some sources of palpable pollution are difficult to detect, *e.g.,* soil pipes discharging into streams and ditches are sometimes so hidden that the most careful and thorough search is necessary to reveal their presence.

The possibility of sheep-dipping tanks leaking or draining into streams and other water supplies should be considered when a site is being chosen for their construction Proximity of a dipping tank to a common water supply is always very dangerous and should not be permitted, as many sheep dips contain arsenic At least one instance is recorded where the water of a stream supplying a public reservoir became contaminated with sheep dip Trout were also killed off below the dipping tank, which was situated close to the stream in question

Wells and Springs. The well-water supply of farms and of houses in country districts often leaves much to be desired from the sanitarian's point of view The wells are commonly of the shallow type, i e they collect surface water, and are badly constructed, imperfectly protected and, consequently, liable to serious pollution Many of these wells were built before the importance of clean water was understood, so that little or no provision was made to exclude the surface water. Indeed, at the present time in isolated country places wells are often sunk in any spot that happens to be most convenient, without any regard to proximity of dangerous soil-washings , such wells may be rubble-lined so as to let in as much of the surface water as possible, the object, of course, being to save labour and expense in deep sinking and in proper lining. On the other hand it must be clearly understood that, because a well-shaft does not penetrate an impervious stratum. the water collected is not necessarily dangerous A shallow well, if sunk to a sufficient depth, which varies with the nature of the soil, and has the upper part properly lined so as to exclude the real surface water, can provide a water of excellent quality The construction of the well is the all important factor

Wells in or near farmyards are very liable to pollution, especially after heavy rain, from the washings of cattle-courts, etc , the drainage of which is usually unsatisfactory When making an examination of a well, very careful attention should be paid to its location. The position of all drains in the vicinity, both surface and sub-soil, should be noted, and also the position of cesspools, sheep-dipping tanks, manure pits and the like The carcases of animals are sometimes buried without due consideration being given to the possibility of subsequent pollution of the water draining from the site of burial into wells Should a buried carcase be found to be the cause of contamination, it is necessary to obtain permission to exhume and remove it, from the Ministry of Agriculture and Fisheries * The area of ground surrounding a well that should be examined depends chiefly on the nature of the sub-soil, and on the depth of the well

See infra.

COLLECTION OF WATER SAMPLES FOR EXAMINATION

Veterinary surgeons are called upon from time to time to collect samples of water with a view to their submission for bacteriological or chemical examination. *The importance of correct procedure in the taking of the samples can hardly be over-estimated* ; upon it depend the deductions which are ultimately drawn from the results of the laboratory examinations. Moreover, as the examination of a water supply is not infrequently carried out when a claim for alleged damage is contemplated, it is essential that the greatest care be exercised in the taking of the sample in order to ensure that *it is not exposed to extraneous contamination or other source of possible error.*

It must be emphasized that the examination of a single sample affords information regarding the condition of the water only at the time that sample was taken, and as most natural waters vary in their composition and degree of contamination with seasonal and other factors the examination of further samples may be necessary. One analysis of a particular supply may give very valuable *information* that would lead to the condemnation of the water that would otherwise pass without suspicion, notwithstanding the most careful examination of the source of supply. On the other hand pollution by sewage may be, and often is, of an intermittent character. Such intermittent contamination is sometimes of a very dangerous nature to people if not to animals, and it may escape detection if the sample for analysis *is taken between the periods when contamination occurs.* A shallow well, for instance, after a long period of dry weather may yield a water that on analysis would be described as "pure and wholesome," but which, owing to faulty steining or other defect in construction, might be seriously polluted with sewage matter washed through the soil after heavy rain. A newly constructed well would almost certainly be condemned if the hygienic quality of its water is considered only on the merits of a sample taken before the water that has collected during construction, and for some time after, has been withdrawn : time must be given for a new well to cleanse itself.

COLLECTION OF SAMPLES FOR BACTERIOLOGICAL EXAMINATION

The following procedure has been recommended by the *Ministry of Health* for the collection and forwarding of water samples for bacteriological examination* :

*See *The Bacteriological Examination of Water Supplies.* Repts. on Pub. Hlth. and Med. Subjects. No. 71 (Revised edit., 1939). H.M.S.O.

Method of Collecting Samples

1.   Sample Bottles should where possible be obtained from the laboratory performing the examination and should be of good quality glass free from excessive alkali If a full examination is required, the bottle should be of about 230 ml capacity, and should be provided with a ground glass stopper having an overlapping rm to protect the lip of the bottle from falling particulate matter in the air and from contamination with the fingers during removal of the stopper

If only a simple or a partial examination is required involving a coliform count or a coliform plus a plate count the bottle should be of the 4-ounce type, holding 130 ml

2.   Sterilization of the sample bottles will have been carried out in the laboratory, either by autoclaving or by dry heat before they are sent out to the person requiring them

3.   Neutralization of Chloramine or Chlorine If the water to be sampled contains or is likely to contain, traces of chloramine or chlorine one or two small crystals of sodium thiosulphate should be placed in the bottle prior to its sterilisation for the purpose of destroying any traces of these chemical reagents

4.   The bottles should not under any conditions be opened until the moment at which they are required for filling with the water and should on no account be previously rinsed out before taking the sample

In collecting the sample carefully remove the cap covering the stopper and hold the bottle with the hand as far away from the neck as possible With the other hand very cautiously remove the stopper and hold it in the fingers until the bottle is filled, carefully replace the stopper and tie down the covering cap On no account must the stopper be laid down or allowed to touch anything.

The object of this procedure is to prevent any of the sample from coming in contact with the hands or with any surface other than the inside of the sterilized bottle

5.   If the sample is to be taken from a tap, previously ascertain that it is supplying water from a service pipe directly connected with the main. Remove any external fittings such as an anti splash nozzle or rubber tube Carefully cleanse both the outside and inside of the tap, paying particular attention to collections of grease inside the nozzle Then turn the tap on full and allow the water to run to waste for 2 or 3 minutes in order to flush the interior of the nozzle and to discharge stagnant water in the service pipe After turning off the tap cleanse the outer surface with a clean cloth. Next, sterilize the tap either by a blow lamp, or by soaking a piece of cotton wool in methylated spirit igniting it and holding it with a pair of tongs close

to the nozzle until the whole tap is unbearably hot to the touch. If the tap is out of doors and exposed to air currents, sterilization is carried out more effectively by means of a blow lamp than by methylated spirit. Cool the tap by allowing water to run to waste for a few seconds; and fill the sample bottle from a gentle stream of water, taking care to avoid splashing.

Occasionally, when the tap is fully turned on, a slight leak of water may be noticed escaping between the spindle and the gland. This is liable to run down the outside of the tap, and by gaining access to the sample, cause serious contamination. Under such conditions no sample should be taken until the leak is remedied.

Unless it is required to ascertain the bacterial quality of the water contained in a service or house cistern, the sample should always be drawn from a tap connected with the main supply or as delivered from the ball-cock into the cistern. Cisterns are often inadequately covered, and the water is accessible to dust and to small animals and insects, such as mice, birds, cockroaches, etc., resulting in contamination and bacterial multiplication.

6. In collecting samples direct from a *stream, lake, reservoir, spring,* or *shallow well,* the aim must be to obtain a sample that is representative of the water which will be taken for purposes of supply to the consumers. It is therefore undesirable to take samples too near the bank, or too far from the point of draw-off; if this is by means of a floating arm, the sample should not be taken too deeply. In a stream, areas of relative stagnation should be avoided. Damage to the bank must be guarded against, otherwise fouling of the water may occur.

In taking the sample, the stopper of the bottle should be removed with the fingers of one hand, and the bottle, held by the bottom with the other hand, should be plunged neck downwards below the surface, usually for a distance of about one foot. The bottle should then be rotated till the neck points slightly upwards, the mouth being directed towards the current. If no current exists, as in a reservoir, a current should be artificially created by moving the bottle horizontally in a direction away from the hand. When completely full, the bottle should be brought rapidly above the surface and immediately re-stoppered. Throughout the procedure care should be taken that no water entering the bottle has previously come into contact with the hand.

7. If the sample is to be taken from a well that is fitted with a *hand pump,* the pump should be continuously operated for at least 5 minutes before the sample is taken. The mouth of the pump is then heated, preferably by means of a blow lamp, and several gallons of the water then pumped to waste. The sample should be taken by allowing the water from the pump to flow directly into the bottle.

8   If from a well from which *pumping is mechanical*, the sample should be collected from a previously sterilized tap on the rising main, or from a near-by tap prior to passage of the water into a reservoir or a cistern.

9   In taking a sample from a well from which the water can be raised only by means of *pail* or *can*, the pail should be thoroughly cleansed and then sterilized by means of a blow-lamp or by pouring into it boiling water which is allowed to remain in contact for a few minutes and then completely emptied out. After sterilization and cooling the pail should not be allowed to touch the ground. The pail should then be carefully lowered into the well without touching the sides and after filling with water should be withdrawn in the same careful manner. The stopper is then removed from the sterile bottle, the bottle being placed on a clean cloth and filled with water by pouring from the pail. Great care should be taken not to contaminate the stopper with the fingers, etc

10   Where there is *no pumping machinery* or other means of raising the water from a well or reservoir in which the level of the water is several feet below the ground surface, special weighted and sterilized containers and bottles can be supplied on request by most well-equipped laboratories

11   Samples from Public Supplies should be taken from a suitable tap supplying water direct from the main and not from a street hydrant, as it is extremely difficult, if not impossible, to sterilize the latter

12   It is frequently very desirable, particularly in the case of wells and surface water supplies, that samples should be taken after rainfall

Particulars to be Supplied in Submitting Samples

1   Name and address of person desiring the examination
2   Reasons for Examination. If the water is suspected of causing ill health, the symptoms should be stated
3   Exact place from which the sample was taken. If from a house tap, state whether drawn through a cistern, or directly from the main
4   State whether Source is a Well, Spring, Stream or Public Supply
5   State what method of purification or sterilization is used, if any, and at what point it is applied, giving the p p m. of sterilizing agent, employed

6   If from a Well, state —
    (a) Depth
    (b) Whether covered or uncovered and the construction of the cover

(c) Whether newly constructed or with any recent alterations which would disturb the conditions of the water.

(d) Construction :—
    (i.) Bricks set dry or in cement.
    (ii.) Cement or cylinder lined, and whether puddled outside the lining.
    (iii.) Depth of lining.
    (iv.) Whether bricked above ground surface. If so, height of coping.
    (v.) Method of pumping or other means of raising water.

(e) Proximity of drains, cesspools, or other possible sources of pollution, and distance from source.

(f) Any discoloration of the sides of the well, or other visible indication of pollution.

(g) Nature of subsoil and water-bearing stratum.

(h) When available, a section or drawing of the well and its general surroundings is desirable.

7. If from a Spring, state :—
(a) Stratum from which it issues.
(b) Whether sample taken direct from spring or from a collecting chamber. If the latter, mode of construction of chamber.

8. If from a River or Stream, state :—
(a) Depth below surface at which sample was taken.
(b) Whether sample was taken from the middle or side.
(c) Whether the level of water is above or below the average.
(d) Weather conditions at time of sampling, and particulars of any recent rainfall or flood conditions.
(e) Observations with reference to any possible sources of pollution in the vicinity and approximate distance from sampling point.

9. Does water become affected in appearance, odour or taste, after heavy rain.

10. Date and time when sample was taken and despatched.

Time Interval between Collection and Examination of Samples

Owing to the rapid and often extensive bacterial changes which may take place in samples of water the shorter the time elapsing between collection and examination, the more reliable will be the results. All samples should therefore be despatched immediately after collection by the quickest route to the Laboratories, the time occupied in transit being preferably less than six hours.

If the time from collection of the sample to its delivery at the

laboratory is not likely to exceed six hours, the sample may be packed in a suitably insulated box. If a longer time is likely to elapse, then ice should always be used. The ice should be placed in a separate closed container and *not* in direct contact with the sample bottle, as this would involve grave risk of contamination of the sample

COLLECTION OF SAMPLES FOR CHEMICAL EXAMINATION

The procedure for the taking of water samples for chemical examination is in essentials similar to that for the bacteriological examination, but the following points of difference may be noted

1. The amount of water required is about half a gallon. Clear glass Winchester bottles having well fitting glass stoppers or rubber bungs are the most suitable type of container for holding the sample
2. Sample bottles need not be bacteriologically sterile but must be chemically clean. If bottles cannot be obtained from the laboratory making the analysis clean ones must be chosen these should be thoroughly washed rinsed with chromic acid and followed by repeated rinsing with clean water preferably distilled
3. When filling the bottle with the water to be tested the bottle should be rinsed at least twice with this water before taking the final sample which is to be sent to the laboratory
4. If the object of the intended analysis is to test the action of the water on the service pipes as for instance for lead solvency the water should be allowed to stand in the pipes over night and the first water drawn off in the morning taken for examination

BACTERIOLOGICAL EXAMINATION OF WATER SUPPLIES

An understanding of the significance of the results obtained by the bacteriological examination of water supplies presupposes a knowledge of the possible bacterial forms which may be found in water. These forms may be broadly classified into two main groups. Firstly, sapro phytic bacteria which are indigenous to water, are adapted to live and multiply at temperatures lower than body heat, e.g. at 20-22°C, and derive their nutriment from decaying organic matter. These free living forms are of little importance from the hygienic standpoint, except that their presence in a water in very large numbers denotes an abundance of organic matter. The second broad group which may be called the adventitious water micro-organisms, are introduced from outside sources and are incapable of surviving in water for an indefinite period. Amongst these are included bacteria in water for an from the air by rain or snow soil bacteria washed in after heavy rainfall and excretal bacteria from human or animal sources. It is with the two last named that the bacteriological examination of water supplies is almost entirely concerned

It has already been mentioned that the present bacteriological

techniques used for the detection of sewage pollution of water supplies are directed to the demonstration of known excretal bacteria, especially organisms of the coliform group, and, to a lesser extent, faecal streptococci and *Clostridium welchii*. The reason for this greater concentration on the coliform bacilli is partly because of the greater ease with which they can be demonstrated by cultural methods, and partly because *Cl. welchii* has been found to survive considerably longer in water than members of the coliform group. The presence therefore of this organism alone in a water sample may indicate a pollution more distant in time than is the case with members of the coliform group.

Coliform Bacilli. The coliform bacilli constitute a group of organisms of diverse origin. Broadly speaking, there is one group, or more correctly sub-group, of which the characteristic member is *Bact. coli*, whose natural habitat is the human and animal intestine; apart from excretal contamination, it is rarely found outside the animal body. Members of the other sub-divisions of the coliform group appear to have their primary habitat in the soil and on vegetation and may, therefore, be regarded as saprophytes; these comprise the *Bact. aerogenes* and *Bact. cloacae* sub-group, the so-called intermediate sub-group, and a fourth or irregular sub-group of organisms that do not fit clearly into any of the other three groups. All four sub-groups may be found in sewage.

The organisms of the aerogenes-cloacae and intermediate sub-groups are commonly referred to as the I.A.C. (intermediate—aerogenes—cloacae) group. Organisms of the I.A.C. group are frequently found in the intestinal canal of man and animals, to which they gain access via the food and drink, but they are seldom present in this situation in numbers equal to those of the typical *Bact. coli*. So far as is known the typical *Bact. coli* (or type 1) does not normally lead a saprophytic existence outside the human and animal intestines. It is the dominant organism found in faeces, and for this reason is commonly referred to as "faecal coli," whilst the I.A.C. group is referred to as "non-faecal coli."

The observations of various workers suggest that at ordinary temperatures members of the I.A.C. group tend to survive longer in water than do faecal coli, though factors other than temperature probably play a part in determining the relative length of survival of these organisms. Since *Bact. coli* does not normally live for any length of time outside the intestinal tract of man and animals, the presence of this organism in water can be regarded as almost certain evidence of recent excretal pollution of human or animal origin. The

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further significance of the coliform group as an indication of the nature and time of pollution will be returned to later. It may be mentioned here, however, that there is no very satisfactory method at present for distinguishing between faecal coli of human origin on the one hand and those of animal origin on the other. A consideration of the topographical circumstances relevant to the water supply under examination may sometimes help in assigning faecal coli to their probable source. For example, in the case of upland surface waters where sheep commonly graze the gathering grounds and in the absence of any known sources of human pollution, the faecal coli isolated from samples are in all probability of animal origin. A similar conclusion may sometimes be arrived at in the interpretation of the bacteriological findings in the case of a well or stream water, where the topographical survey on the spot indicates excretal pollution by livestock and, as far as can be seen after careful investigation, there is little possibility of contamination from human sources.

Clostridium Welchii. This organism is normally an intestinal inhabitant. It is a spore-forming organism, which survives for a considerably longer time in water than the coliform bacilli, and usually resists chlorination. Its presence in water indicates that faecal pollution has occurred, and the finding of *Cl. welchii* in the absence of members of the coliform group indicates that the contamination is not of very recent date. The chief value of looking for this organism would seem to lie in the detection of remote or intermittent pollution in surface or shallow water supplies, such as those from a pond or a well. Supplies from these sources are commonly used on farms and by small rural communities and their frequent examination by the coliform test is seldom, if ever, practicable. An occasional examination for coliform bacilli might in any case yield misleading results, since these organisms might have died out since the last access of pollution. In circumstances such as those mentioned, then, the demonstration of *Cl. welchii* will show that the water is subject to contamination, and will indicate the necessity of taking steps to eliminate the source of pollution or otherwise prevent it gaining access to the water.

Faecal Streptococci. Streptococci of various types are present in a number of situations in the human and animal body. The most characteristic type is that usually referred to as *Str. faecalis*. In human faeces The value of a bacteriological test for the detection of these organisms in water supplies appears to be largely undecided at the present time. Many workers are of the opinion that it adds little to the information

yielded by the test for coliform bacilli. Other workers, on the other hand, believe that it has a considerable value in assisting the interpretation of bacteriological analysis when the results of the coliform test are irregular or indefinite. Thus, for example, when it is uncertain whether certain irregular types of coliform bacilli are or are not of faecal origin, the accompanying presence of faecal streptococci will constitute presumptive evidence that the irregular coliform types are derived from faeces.

THE COLIFORM TEST

The bacteriological examination of water supplies for organisms of the coliform group comprises the most suitable and the most generally applicable test for evidence of pollution. The complete examination comprises a number of separate procedures, by which it is possible not only to demonstrate the presence of coliform bacilli, but also to assign them to the four sub-groups already mentioned. It is beyond the scope of this book to describe the techniques used in the bacteriological examination of water, but some information of a general kind will be given as an aid to the understanding of bacteriological reports on water samples submitted for examination.

The complete test for coliform bacilli comprises the following procedures—(i.) the presumptive coliform count, (ii.) the differential coliform test, (iii.) and (iv.) and plate counts at 22°C. and 37°C. The particular test or combination of tests required for any given sample submitted for examination will be decided by the bacteriologist after consideration of the relevant details pertaining to the circumstances under which examination of the water supply in question became necessary. The importance of supplying as full particulars as possible when forwarding samples to a laboratory for examination can, therefore, be readily understood.

By the plate counts at 22°C. and 37°C., the total number of viable bacteria per unit volume of water is determined. Most of the bacteria growing at 22°C. are saprophytic types which are non-pathogenic to human beings or animals. It may be thought that the plate count at 22°C. is immaterial so far as judgment of the hygienic quality of the water is concerned; to some extent this is true, but it may be pointed out that this count affords some indication of firstly the amount of food substance available for bacterial nutrition, and secondly the amount of soil, dust and other extraneous material carrying bacteria with it that has gained access to the water. On general grounds the greater the number of organisms developing at this temperature, the larger is the amount of available organic matter present, and the less

suitable is the water for human consumption The bacteria developing at 37°C on the other hand, are mainly parasitic or potentially parasitic, though not necessarily pathogenic, types derived from soil, sewage or excretal material, and must therefore be regarded as evidence of the possible presence of pathogenic types such as members of the typhoid-paratyphoid group

The presumptive coliform count, together with the differential coliform test, is by far the most delicate index of excretal pollution. These tests are carried out on a quantitative basis and the results reported, according to the most recent recommendations, in the following manner —

     (a) Probable number of coliform bacilli present in 100 ml

and   (b) Probable number of faecal coli present in 100 ml

INTERPRETATION OF BACTERIOLOGICAL EXAMINATION

The interpretation of the results of the bacteriological examination for coliform bacilli, as well as those for the other intestinal bacteria, calls not only for careful consideration of all the relevant factors, but also for considerable experience in this work Final decisions have yet to be reached as to the meaning of all the data obtainable in the laboratory, and any conclusions reached must still be to some extent reflections of individual experience and, therefore, variable The bacteriological condition of a water, too, has to be considered in relation to many other factors such as season, nature and topography of the source of supply, the frequency of examination, etc The Report of the Ministry of Health on "The Bacteriological Examination of Water Supplies," already cited, indicates that all that can be done in the light of present knowledge is to formulate some generally accepted deductions and to suggest broad lines for the hygienic classification of waters The following quotations taken from the above-mentioned Report give the most authoritative information available at the present time regarding the interpretation of results and the hygienic classification of water supplies —

"Our knowledge of the importance of the different coliform types is still very deficient, but we can summarise the present position, so far as it affects Great Britain, in terms such as the following —

(1) *Bact coli* I is essentially an index of recent excretal pollution. The finding of this organism in water in more than minimal numbers can never be safely ignored

(2) The presence of organisms of the I A C group in water in the absence of faecal coli may be due either to (a) contamination of the water with soil ; (b) contamination of the water with excretal

material at a time sufficiently distant to allow faecal coli to die out ;
(c) contamination of the water with the excreta of a person who is
discharging the I.A.C. in almost pure culture ; this must be relatively
uncommon ; (d) inadequate treatment of an initially polluted water
with chlorine, which has only succeeded in killing off the more
susceptible faecal coli. Which of these explanations is correct can
be determined only by inquiry into the source and history of the
water.

(3) The finding of a high proportion of faecal coli among the
total coliform organisms is indicative of heavy or recent excretal
pollution. On the other hand, a result showing that the majority
of the coliform organisms appear to belong to the I.A.C. or to
irregular types may be regarded as indicative of a slight, infrequent,
or remote excretal pollution ; or perhaps, if no faecal coli are
present at all, of simple contamination with soil that may or may
not have been excretally polluted some time previously.

(4) In practice it is unwise to neglect completely the presence
of organisms of the I.A.C. group. Even though no faecal coli can
be found, their presence may indicate a minor degree of pollution
which at any time might become serious. Their appearance in a
water, particularly a deep well water, from which they are normally
absent, sometimes heralds the advent of pollution, and enables steps
to be taken in time to stop further pollution or, if this is impossible,
to protect the consumer by suitable treatment of the water.

(5) In general terms, the presence of faecal coli denotes recent
and possibly dangerous excretal contamination, which must be
urgently attended to. The presence of I.A.C. in an untreated
water suggests less recent contamination, which though not
immediately dangerous is nevertheless sufficient to call for further
steps towards obtaining greater purity of the supply. The presence
of I.A.C. in a treated water suggests either inadequate treatment
or the access of undesirable material to the water after treatment.

"SUGGESTED CLASSIFICATION OF WATERS"

"The bacterial flora of water is determined by so many factors
which vary from one source of supply to another that it is impossible to
lay down hard and fast standards for waters as a whole. The aim must
rather be, on the basis of frequent examinations, to establish a standard
for each individual water, departure from which may be at once viewed
with suspicion. Nevertheless, experience has shown that it is justifiable
to expect waters intended for public supply to come up to a certain
standard of purity. The particular standard laid down must vary

with the type of water—deep or surface water, filtered or unfiltered, chlorinated or unchlorinated The standards must not be interpreted too rigidly ; on the other hand, no serious departure from them ought to be viewed with complacency.

"Since the apparent number of organisms present is subject to various sampling and technical errors, the use of quantitative data is apt to be misleading to those who are not fully cognizant of the limitations of the technique employed For this reason we suggest that on the basis of his results the bacteriologist should allocate the water to a particular class, which will leave no doubt in the mind of water engineers, sanitary inspectors and similar persons of the general bacteriological standard of the water

"Since the plate counts are dependent so much on the particular type of water under investigation, it is impossible to use them for general standards For this purpose we must rely on the coliform test Again, since it would be impracticable and confusing to lay down grades for every type of water, we are confining our classes to piped supplies intended for distribution to populations of more than minimal size With very small supplies the frequency of examination cannot be expected to be sufficient to justify classification of waters on bacteriological grounds As is pointed out later, the quality of such supplies must be judged very largely on topographical examination

"Ideally, coliform bacilli should be absent from 100 ml of water, but such an ideal standard would exclude many waters that can be and are consumed with impunity for indefinitely long periods In setting out the following classification, we are permitting a probable number of 2 coliform organisms per 100 ml in non-chlorinated piped supplies

Piped Supplies

		Presumptive Coliform Count per 100 mL
Class 1	Highly Satisfactory	
Class 2	Satisfactory	less than 1
Class 3	Suspicious	1-2
Class 4	Unsatisfactory	3-10

"In chlorinated piped supplies the water ought to come into Class 1   greater than 10

"Water Taken on Consumer's Premises

"The classification laid down here for piped water supplies refers essentially to the quality of the water entering the distribution service and not to that of the water taken on the consumer's premises Whatever the quality of the water entering the distribution service may be, some slight deterioration is liable to occur during its passage to the

consumer. Organic matter may be sucked in to a variable extent through defective water mains, and further contamination may occur in service reservoirs and cisterns or from washers on, the service taps. It is difficult to lay down standards for water of this type, but if careful comparison between the water before and after distribution shows that any considerable deterioration has occurred, particularly in relation to *Bact. coli* I, then measures should be taken to ascertain the source of the pollution.

"Small Rural Supplies

"In rural districts where reliance has to be placed largely on private supplies, it may be difficult to reach the standard of Class 3. By relatively simple measures, such as the removal of obvious sources of contamination from the catchment area, and by attention to the coping, brick lining, and covering of the well, it should usually be possible to reduce the coliform count for a shallow well water to a level between 10 and 25 per 100 ml. Persistent failure to do this, especially if the water frequently gives a presumptive coliform count of 50 or over per 100 ml., should lead as a rule to condemnation of the supply, though there are circumstances, such as where the pollution appears to be mainly of non-human origin, when an exception may be made to this rule."

CHEMICAL EXAMINATION OF WATER SAMPLES

The complete chemical examination of water in respect of its suitability or otherwise for drinking and for ordinary domestic uses normally includes determination of total solids, pH, hardness, free and albuminoid ammonia, nitrate, nitrite, chlorides, and action on metals. It may also be necessary to examine waters for unusual constituents such as lead, zinc, arsenic, copper, iron, aluminium, magnesium, fluorides and cyanides, whose presence may be suspected from a consideration of the source of supply or from a history of toxic symptoms arising in man or animals drinking the water. Whilst the chemical examination and the interpretation of the results falls strictly within the province of the experienced analyst, some knowledge of the procedures involved will greatly aid the veterinary surgeon in appreciating the significance of the analytical findings.

Total Solids. The method of determination employed is briefly as follows :—The residue left after evaporating a measured volume of water is weighed and the result calculated to parts per 100,000 of water. The estimation is usually carried out on filtered water if appreciable quantities of suspended solids are present, so that suspended solids are

reported separately from dissolved solids The residue consists of all the non-volatile substances which were present in solution in the original water The organic content of the residue can be assessed from the appearance of the residue after gentle ignition, considerable charring indicating a high content of organic matter

Satisfactory waters rarely contain more than 80 parts per 100,000 of dissolved solids, and for most purposes should contain much less ; they rarely contain more than a mere trace of organic matter

pH Value. The pH of natural waters is of importance chiefly from the point of view of possible corrosion of metals Waters with low pH values, especially if the acidity is due to dissolved carbon dioxide or to humic acids, are potentially plumbo-solvent , they corrode most metals to some degree Alkaline waters, particularly if the alkalinity is due to dissolved sodium carbonate, are corrosive of zinc It should be pointed out that waters which are neutral in reaction are not necessarily non corrosive, e g neutral solutions of chlorides and nitrates will corrode most metals The pH value of a sample of water should, therefore, be considered along with other determinations, particulary with the qualitative composition of the dissolved solids fraction

Hardness The hardness of water refers to its soap destroying power and is due to the presence of calcium and magnesium salts in solution It is usual to distinguish between waters that are "temporary" hard and those that are "permanently" hard (see pp 21f) Temporary hardness is due to the presence of the bicarbonates of calcium and magnesium in solution, permanent hardness is due to the chlorides, sulphates and, to a lesser extent, the nitrates of calcium and magnesium. Hardness whether temporary or permanent, is expressed as parts of calcium carbonate per 100,000 parts of water , "degrees" of hardness are numerically equal to parts of calcium carbonate per 100,000 parts of water

A total hardness of more than 30 is sufficient to render a water unsuitable for most purposes, although if required for drinking only a considerably higher hardness might be tolerated Waters with hardness less than 5 are very soft, and such hardness values should be considered along with pH value for possible plumbo-solvent action

Chlorides Chlorides are rarely absent from natural waters, being present chiefly as sodium chloride, with occasionally magnesium, potassium and calcium chlorides The chloride content of waters derived from rocks near the sea is invariably high , waters from deep

wells may contain sufficient to impart a brackish taste. The presence of chloride considered alone is therefore of little significance as regards hygienic quality, but as sewage contains appreciable quantities of it, if the chloride is present together with free ammonia, nitrite or appreciable quantities of nitrate, this finding may support an indication of sewage pollution. Uncontaminated surface waters (except near the sea) rarely contain more than 2 parts of chloride per 100,000; well waters may contain considerably greater quantities.

During World War I., it was found in Palestine that most troop horses would drink water with a saline content of 800 parts (as NaCl) per 100,000, but few would drink it with 900 and none with 1,000 parts per 100,000. Horses suffered more than mules and camels when the only water supply was brackish.*

The Nitrogenous Constituents. Uncontaminated water supplies are rarely completely free from nitrogenous constituents, and in such waters nitrogen may be present in the form of humic acids or nitrates. Waters contaminated with sewage or other decaying organic matter may contain, in addition to these, ammonium salts or easily de-composable amides, and nitrites. As ammonium salts and nitrites are quickly oxidised in natural waters to nitrate, their presence is taken as a strong indication of recent contamination with sewage.

Quantitatively the ammonium salts and easily decomposable amides are estimated by distilling a sample of the water made alkaline with sodium carbonate; the amount of ammonia distilling off is estimated, calculated to part per 100,000 and reported as "Free Ammonia." Humic acids and the more complex nitrogenous compounds such as protein do not liberate ammonia on boiling with sodium carbonate, but do so when distilled with an alkaline solution of potassium permanganate. This ammonia is estimated, calculated to parts per 100,000 and reported as "Albuminoid Ammonia."

Satisfactory waters rarely contain any free ammonia at all, and the presence of more than 0.005 parts per 100,000 must be regarded as significant of pollution. If the amount of free ammonia present is greater than the amount of albuminoid ammonia, then sewage contamination is certain. Many satisfactory waters, *e.g.* peaty waters, contain appreciable quantities of albuminoid ammonia, but such waters yield their albuminoid ammonia slowly, and they contain only traces of free ammonia. In waters other than moorland waters, the albuminoid ammonia may be significant of sewage pollution if it is present in concentrations greater than 0.01 parts per 100,000.

The presence of nitrate is of no significance in the absence of other

* *Off. Hist. of War: Veterinary Services.* 1925, p 139.

nitrogenous constituents If, on the other hand, free ammonia is present then the presence of nitrate is an added indication of pollution.

Reducing Power or "Oxygen Absorbed." The pollution of natural waters is invariably accompanied by an increase in the amount of organic matter present in solution This dissolved organic matter is easily oxidised and the amount of available oxygen absorbed by the water from an oxidising solution gives a measure of it The ability of water to reduce a dilute solution of acid potassium permanganate is referred to as the Reducing Power or Oxygen Absorbed figure, and is reported as parts of available oxygen absorbed per 100 000 parts of water

Many natural waters contain dissolved organic matter that is innocuous Moorland waters, for example, contain peat acids, and if the reducing power of such waters is not in excess of about 0 1 parts per 100 000, they may be regarded as satisfactory In the case of other waters the reducing power should not normally be in excess of 0 05 parts per 100,000 In all cases the reducing power should be considered in the light of the other estimations, e g free ammonia and chloride that indicate possible contamination

It is difficult to state hard and fast rules defining limits of impurities that should be allowed in water The chemist takes many factors into consideration before arriving at an opinion The following figures however, give some indication as to the limits generally permitted

Provisional Standards
Parts per 100 000

	Satisfactory	Usable	Doubtful	Contaminated
Free Ammonia	nil-0 002	0 002-0 005	0 005 0 007	above 0 007
Albuminoid Ammon	nil-0 005	0 005-0 010	0 010-0 014	above 0 014
Nitrates	nil	trace	0 200	1 00
Oxygen absorbed —				
Upland Surface	0 10	0 10-0 30	0 30-0 40	above 0 40
Other than Upland Surface	0 05	0 05-0 14	0 14-0 21	above 0 21

PHYSICAL EXAMINATION OF WATER SAMPLES

A water sample is examined physically for colour, turbidity, odour, taste, and electrical conductivity

Colour and Turbidity Natural waters rarely show colours other than yellow or reddish brown, which usually indicate the presence of peat acids or, in the case of turbid water, suspended particles of clay or of iron oxides , occasionally algal growth is responsible for the appearance of a green or red colour

Few waters which can be considered satisfactory contain appreciable quantities of suspended organic matter. Its presence in any quantity encourages the growth of micro-organisms, renders the water difficult to filter, and frequently makes sterilization difficult. Suspended mineral matter, on the other hand, is less objectionable. Its presence tends to be seasonal, occurring usually after periods of heavy rain, although when in the form of hydrated oxide of iron it appears as a permanent turbidity in ferruginous waters.

Odour and Taste. Odour and taste can only give an indication of sewage contamination if it is excessive, but they are useful in detecting other unusual types of contamination which are difficult to detect chemically. For example, the accidental contamination with small quantities of paraffin oil or similar substances sometimes occurs ; chemical methods may not be sufficiently sensitive to detect traces of these compounds, and in such cases taste and smell may be the only guides to the presence of these contaminants.

Peaty water nearly always has a slight odour. Certain waters contain sulphuretted hydrogen. Decomposing aquatic fauna and flora in service mains are not infrequently the cause of "smelly" water.

Rain water has a flat insipid taste. Soft waters taste "soft." Ferruginous waters taste of ink. Waters containing much sodium chloride have a brackish taste. The water from newly laid mains may have a tarry flavour. Water treated with bleaching powder tastes of chlorine if the available chlorine in the water exceeds three or four parts per million. Hard waters, and also those containing nitrates and carbonic acid, are more palatable than soft waters or those free from gas in solution.

Electrical Conductivity. Chemically pure water is a non-conductor of electricity, but the solution in it of ionisable salts renders it conducting, the ease with which an electric current is transmitted being directly proportional to the concentration of ionisable salts in solution. This fact is made use of in the examination of natural waters, the electrical conductivity of the water being an indirect measure of the amount of dissolved substance present in it. It should be noted that, by itself, the electrical conductivity gives no indication of the nature of the substances in solution. Values of electrical conductivity for natural waters vary from about 100 gemmhos for soft waters derived from the older crystalline rocks to about 2,000 gemmhos for very hard waters derived from the newer and softer rocks ; sea water has a conductivity of about 50,000 gemmhos.

In the absence of sodium salts, the electrical conductivity is pro-

portional to the hardness, one degree of h conductivity by about 20 units   Thus such a water with a conductivity of 500 units would possess a hardness of approximately 25°   This relationship holds generally, but breaks down when applied to the alkaline waters derived from the Lower Tertiary rocks of the London Basin

The determination of electrical conductivity finds its greatest use in indicating changes in the *amount* of dissolved solids present in a water where the *composition* of the dissolved solids fraction is known and is fairly constant

MICROSCOPICAL EXAMINATION OF WATER SAMPLES

The microscopical examination of water is carried out for the detection of particulate inclusions, and such examination may often be of great diagnostic value   The method of procedure is to allow a sample of the particular water under consideration to stand in a covered glass vessel for about 24 hours so that the suspended solid matter may settle to the bottom   The supernatant fluid is then syphoned off and portions of the sediment transferred to a glass slide for examination under a low power   In the sediment may be found insoluble mineral matter, dead vegetable and animal detritus, and vegetable and animal organisms in the living state   The identification of any particular substance in the deposit is a difficult matter even for the expert biologist

The identification of particulate mineral matter may in part be effected by the aid of the microscope and completed by the use of chemical reagents   Sand appears as large angular masses, clay as round, smooth globules, chalk smooth, but of crystalline appearance If chalk is suspected, a little dilute hydrochloric acid run under the cover glass will settle the point, the chalk particles will disappear from the field with the evolution of gas   Oxide of iron shows as a reddish brown amorphous mass which may be seen to turn blue if a drop of potassium ferro cyanide solution be added to the material on the slide

Dead animal matter is more easily recognised than is vegetable matter   Vegetable tissues should, however, always be looked for and, if possible identified so that they may be assigned to their possible source of origin   Linen and cotton threads and portions of household vegetables point to the presence of domestic waste in the water   Wool, hair, muscle fibres and starch granules are evidence of organic contamination, and strongly indicate the possibility of pollution with sewage matter

WATER SUPPLIES OF DOMESTICATED ANIMALS

Hygienic Requirements. It would be altogether impracticable in a water supply used exclusively for animals to insist on the same high standards established for water intended for human consumption. On dairy premises, however, where the drinking water of the animals and that used for the cleansing of cowsheds and utensils are drawn from a common source, the water should fulfil all the hygienic requirements demanded of a safe drinking water for man. Supplies to dairies and cowsheds apart, it is, nevertheless, desirable to provide livestock with a drinking water which is, as far as possible, faultless in character.

As is the case with human water supplies, it is difficult to formulate positive hygienic standards for animal supplies because of the many factors involved. It is, therefore, probably easier to state what the character of the water should not be than to lay down any particular standards to which it should conform. Some of the undesirable features may be illustrated by reference to the old-time farm pond, from which not only were the animals watered, but which in many cases served also as a source of supply for the farm household and dairy. These ponds are not infrequently situated close to the farm buildings and to the dungheap, and constitute a serious menace to the health of live stock. Cattle and horses wading into the ponds in order to drink frequently grossly contaminate the water with faeces and urine, thus creating a focus for the spread of tuberculosis, Johne's disease, contagious abortion, and entozoal and other diseases. It is possible that these ponds may also be concerned in the spread of mastitis ; it is certain that such filthy water must be a grave source of milk contamination if it becomes splashed on the cows' udders. It should be realised that efforts to control disease in livestock will to a great extent be wasted, so long as the principal, and indeed often the only, water supply is subjected to gross pollution of the kind indicated above. If a stagnant water supply, such as a pond, must as a last resource be used for the watering of farm animals, it is essential for the maintenance of health that the animals be prevented from actually wading into the pond.

One of the first requirements in a drinking water for animals is that at no time should the supply be open to contamination by pathogenic micro-organisms or the eggs and larvae of animal parasites. Secondly, the possibility of mineral poisons such as lead or arsenic gaining access to the water must also be rigidly guarded against. In addition to these primary conditions, the physical characters of a water often provide good indications as to its suitability or otherwise as a source of supply. The water should be free from objectionable

taste and smell; the willingness with which animals drink it may be some criterion in this respect. A water showing marked turbidity and the presence of much suspended particulate matter should be looked upon with suspicion, since these characters often indicate that it has been exposed to dangerous pollution by manurial excreta or other organic wastes.

Animal Diseases Associated with Water Supply. There is little exact information concerning the rôle which water plays in the dissemination of infectious diseases of animals. That it plays an important part there is no doubt, but the great technical difficulties
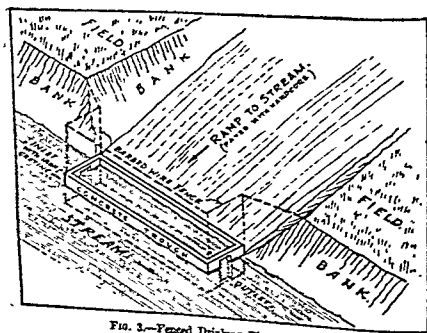

Fig. 3.—Fenced Drinking Place in Stream.

associated with the demonstration of pathogenic micro-organisms in water supplies hinder a full and complete appreciation of the dangers arising from contaminated sources.

It is commonly believed that Johne's disease of cattle is spread mainly by the contamination of water and other ingesta with infected faeces. The spread of the disease via these agencies is clearly bound up with the ability of the Johne bacillus to survive outside the animal body, and whilst this, because of the similarity of the bacillus to the tubercle bacillus which is known to survive for long periods, has been assumed to be long, exact data on the problem until recently have been scanty. Lovell et al.[*] (1944) have, however, described a series

* Lovell, R., Levi, M., and Francis, J. (1944) *J. Comp. Path.*, 54, 120-129.

of experiments to test the viability of Johne bacilli outside the animal body after exposure under natural conditions. These workers found that cultures of Johne bacilli remained alive in sterilized water kept in a cupboard in the laboratory for upwards of nine months, and that intestinal scrapings from cases of Johne's disease may contain viable bacilli for upwards of 163 days after mixing with unsterilized river water. It thus appears equally likely that the Johne bacillus possesses considerable capacity for survival when voided in infected faeces into water, and that, therefore, cattle should be prevented from entering and polluting ponds and other sources of water supply. The draining or fencing of farm ponds subject to contamination, and from which cattle may drink, is therefore sound policy.

Other common infections of livestock which may occasionally be water-borne include tuberculosis, bovine contagious abortion, anthrax, blackquarter, swine erysipelas, and parasitic infestations such as fascioliasis, parasitic bronchitis and parasitic gastro-enteritis. One is reminded that in times past the public watering-trough in towns and cities was a frequent means by which glanders and strangles were spread among the horse population. It is no less certain to-day that the common watering-place, wherever it may be, and whatever form it may take (pond, stream, trough, bowls or other utensils), is an important factor in the spread of disease among farm livestock, dogs and poultry.

In the fields, animals are often dependent on a stream for their water supply. If, as is all too commonly the case, this stream receives the cowshed and other manurial effluents from several farms along its course, then such a water source must be regarded as a grave potential danger by which disease is spread from farm to farm. It is a familiar country sight to see cattle wading knee-deep in streams and ponds, and sometimes defaecating into the water from which they take their drink. However picturesque this scene may appear, it is, from the health point of view, highly objectionable in that it affords a ready means for the dissemination of many of the common bacterial and parasitic infestations of animals that gain entrance to the body via the alimentary canal. Disease may thus be spread not only within the herd but also to other herds drinking the polluted water downstream. An effort may be made to eliminate gross pollution of this kind by fencing the drinking places so that animals are prevented from wading into the stream. A concrete trough may also be placed at the edge of the stream (see Fig. 3), which to some extent will help to prevent the drainage from the approach to the drinking-place gaining access to the stream at the point where the animals drink. A similar method may be adopted for preventing the direct faecal pollution of ponds

from which animals perforce have to drink in the absence of a more satisfactory form of supply. A method of protecting a field-trough against such pollution is shown in Fig 4

Pigs and poultry will contaminate the water placed in drinking utensils unless prevented by some means from doing so. There are various drinking appliances available which effectively prevent the fouling of water

Sewage-polluted Water. It has been affirmed that cattle may be rendered ill by drinking water containing "sewage". In this connection it is important to make it clear that there are two kinds of sewage,
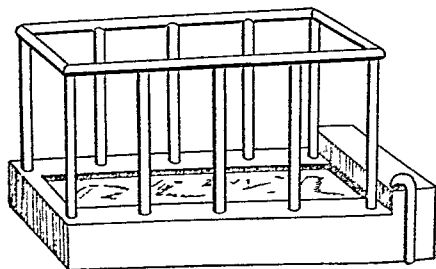

Fig 4—Cattle Drinking Trough designed to prevent faecal contamination.

namely household or domestic sewage and industrial sewage. The latter consists of waste products from factories, and its composition will naturally vary with the industry concerned, but if it contains some "poison"—whether chemical or bacteriological—it is liable to cause harmful effects on stock. Domestic sewage is also a product of variable composition and consists of water containing human faeces and urine as well as kitchen waste. There is usually considerable dilution of human excrement, and the Royal Commission on Sewage Disposal recommended that in the construction of sewage works a flow of 25 gallons per head of the population per day should be allowed for. Before liberation into streams or rivers the sewage must be treated so as to attain a certain standard of purity (see Section on "Sewage Disposal")

It is especially in connection with the effluent from works engaged in the disposal of domestic sewage that so-called "sewage-poisoning" of animals, and particularly cattle, has been alleged. On a number of occasions complaints on this score from farmers have been pressed with success in the Courts, the basis of the claims being that the cattle showed "illness" when allowed to drink from the sewage-contaminated stream, and that they recovered when prevented from doing so. Such evidence, however, is not scientifically sound, because it does not exclude the possibility that the illness may have been caused by pathogenic bacteria in the stream which were derived from the intestines of the animals themselves. It has been stated that the symptoms of so-called sewage-pollution in cattle resemble in some respects those of Johne's disease, and there can be no doubt that streams contaminated with faeces from cattle with Johne's disease play a large part in the spread of this infection. Intestinal parasites such as nematodes are also quite commonly transmitted in a similar manner, and in countries where the human population carries the cestode *T. saginata*, cattle grazed on the sewage farms become invariably infested with *Cysticercus bovis* from the eggs which have been passed in the human faeces.*

The possibility is not disputed that bacteria pathogenic for cattle may be conveyed by water just as human typhoid is so transmitted, but those who believe in sewage-poisoning allege that there is some agent proper to human sewage which is poisonous to cattle. Here again there is no scientific evidence that any such agent exists, and, indeed, there is evidence that human sewage does not injure cattle. Thus, in an experiment † carried out at the Royal Veterinary College, London, by Minett, Wooldridge and Sheather, sewage effluent from a modern sewage disposal plant, as well as diluted crude sewage, was consumed in very large quantities by three cattle for 21 months, and the animals remained in thriving condition. There is in addition a large volume of evidence that cattle and other stock are commonly kept on sewage farms where they eat grass wet with sewage and even drink sewage with no apparent harm. These facts do not imply that an impure water supply would be recommended for cattle, but they do show that cattle can drink with impunity water which is highly impure by chemical and bacteriological standards.

On the other hand, there is plenty of evidence that some industrial effluents are definitely poisonous for animals. Thus cyanides in toxic amounts have been found in the drinking water of animals on several occasions by Clough,‡ the cyanides being discharged into drinking

* Penfold, W. T., and Penfold, H. B., 1937, *T. Helminth.* 15, 37.
† Minnett *et al.* (1934). *Vet. Rec. XIV.*, 147.
‡ Clough (1933). *Vet. Rec. XII.*, 538.

water in the effluent from factories   He records the death of two
cows from drinking water, two samples of which yielded 1 grain and
1½ grains of cyanide (calculated as HCN) per gallon , traces of copper
and cadmium were also found , the effluent in this case was discharged
into the drinking water from electrical works   In another case two
cows were found dead by a stream, the water of which was found to
contain 0 25 of a grain, 0 20 and 0 02 of a grain of cyanide (calculated
as HCN) per gallon , the effluent was from a factory manufacturing
photographic materials   In a third case two cows were found dead
by a stream, the water of which contained 2 grains of HCN per gallon ;
the effluent was discharged into the stream from an aeroplane factory
Clough also records the death of a number of ducks   The stream to
which they had access was found to contain 6 grains of cyanide
(calculated as HCN) per gallon   The sample of water yielding this
quantity of cyanide was taken soon after the ducks were found
floating dead on the stream , other samples taken twelve, twenty-four
and forty-eight hours later contained 3 grains, 1 grain and 0 3 of a
grain of HCN respectively per gallon   Copper was also found in this
water, and Clough concludes that cyanide was probably present as
copper cyanide   The pollution in this case was effluent from a factory
manufacturing apparatus for wireless telegraphy

Polluting discharges may remain for a long time in tidal waters
Southgate, Pentelow and Bassindale,* when investigating the cause of
death of salmon and sea trout smolts in the estuary of the Tees, found
a central belt of contaminated and permanently partially deoxygenated
water which moved to and fro with the tides, the sewage taking several
days to reach the sea   In this case the death of the smolts was due to
the cyanides and tar acids of coke-oven effluents

THE EXAMINATION OF WATER SUPPLIES FOR ANIMALS

In the examination of water supplies intended exclusively for
animals, the topographical survey is of the greatest practical import-
ance, and usually exceeds in value the bacteriological and purely
chemical methods of examination, which must be carried out more or
less regularly if they are to furnish a basis for accurate conclusions
In the tracing of certain disease outbreaks, local inspection of the
source and circumstances of the water supply serves especially to reveal
the possibility for contamination of the water with disease producing
factors

Many farms, and particularly the pastures, are entirely dependent

* Southgate *et al* Biochem. Journ., 1932, XXVI , 273

on surface waters as the means of supply. Here the examination calls for a search for possible sources of pollution, amongst which may be mentioned the proximity of animal excreta, stable wastes, and carcases to the sites at which the water is drawn. Contamination of the gathering grounds and drainage areas for streams and ponds must likewise not be overlooked. With springs and wells situated in limestone formations, the existence of cracks and fissures in the strata may be of significance as these furnish an avenue for the access of polluted surface waters and the drainage from stables, cowsheds, cesspools and the like. Attention must be given to the construction of wells, particularly as to the means adopted for the exclusion of surface and drainage water.

Although the topographical survey, when carefully carried out, will usually provide the necessary information regarding a water supply for animals, occasions will arise when bacteriological and chemical examinations are necessary, as for example when the presence of toxic impurities is suspected, or when the supply is also to be used for dairy purposes. In such circumstances the examinations must be carried out in specialist laboratories, and the veterinary surgeon in the field must, therefore, be aware of the procedure and method of taking water samples, and must be able to furnish all the local details which may be of help to the laboratory workers in assessing the results of their examination.

The Amount of Water Required by Domestic Animals. The amount of water required daily by domestic animals depends upon their size and functional activity, the nature of their food, and the season. A horse under average stable-feeding conditions and doing moderately hard work will drink from 8 to 10 gallons during the day, but if fed chiefly on fresh green grass he will naturally drink less. Provision should be made for 8 gallons for drinking, while for general stable purposes an additional 6 or 8 gallons may be necessary.

Dairy cows need 4 to 5 lb. of water for each 1 lb. of milk produced ; this quantity covers the requirements for both maintenance and production. For maintenance alone, under average conditions, 7 to 8 gallons will usually prove ample for a 1,000 lb. cow, while 1¼ gallons should be allowed for each gallon of milk produced. The importance of allowing milk cows free access to fresh water cannot be over-emphasized, and if they are being stall-fed the provision of some form of automatic water-supply is almost essential.

In addition to drinking water for dairy cattle, ample supplies must also be available for cooling and for cleansing purposes. Efficient cooling may take up to 5 or 6 gallons of water for each gallon of milk

produced if refrigerant cooling is not available, whilst cleansing will need some 10 gallons per cow. It is estimated that, for all purposes, at least 25 to 30 gallons per cow per day is necessary, but where possible it may be desirable to budget for a daily supply of about 50 gallons. A considerable saving in the total water expended may be effected if water that has passed through the cooler is made available for further use, either for washing the cows and cowshed, or for watering the stock.

The water requirements of fattening cattle are probably somewhat greater than those of dry cows because of the extra demands for both growth and fattening. The quantity actually drunk will vary according to the extent to which succulent foodstuffs form part of the diet.

The generally accepted ruling as regards the supply for pigs is that 3 lb of water should be allowed for each 1 lb of meal up to 100 lb body weight, and thereafter the demand will gradually fall to half that quantity at 200 lb body weight. The 3 to 1 proportion also applies to breeding sows of all weights; an adult suckling sow eating on an average 16 lb of meal per day will require about 50 lb of water, but some sows may need considerably more than this amount.

The requirements of poultry are theoretically satisfied by a supply of water equivalent to twice the weight of the dry food eaten. When in full lay a hen will drink up to $8\frac{1}{2}$ oz. per day, so that one gallon of water should suffice for 18 to 20 hens.

SECTION II

SANITATION

THE DRAINAGE OF BUILDINGS

A COMPLETE drainage system may conveniently be divided, for descriptive purposes, into three sections, which are all inter-connected :— *(a)* that part inside and outside the building, situated above ground level and leading to *(b)* the underground drain-pipes and fittings which, in turn, are connected to *(c)* the public sewer, cesspool, septic tank or other means of disposal. In animal buildings of modern design, the liquid and semi-liquid excreta are conveyed to the outside drains by open surface channels.

The general principles governing the design of any drainage system, whether for human or animal habitations, may be enumerated as follows :—

1. The pipes should be made of non-absorbent material, and be laid with air- and water-tight joints.
2. The diameters of the pipes should be proportionate to the work they are called upon to do.
3. The drains should be laid in straight lines between points of access, all changes of direction or gradient being open to inspection.
4. There should be no right-angled junctions, all connections being so made that the incoming drain points in the direction of the flow of sewage.
5. The drains should be laid to gradients which will ensure their being self-cleansing or, if this is impossible owing to the nature of the levels, automatic means of flushing should be provided.
6. All inlets to foul drains should be trapped, excepting vertical soil pipes from human dwellings, at the feet of which no traps should be used.
7. No drains should pass under buildings if it is possible to arrange them otherwise.
8. All entrances to drains should be outside the building.
9. There should be ample means of access for inspection.
10. The drainage should be disconnected from the sewer or other outfall by means of a proper intercepting trap.
11. The drainage system should be properly ventilated.

12. It is desirable to provide a separate system of drains to take the rainwater in most cases

Drainpipes. Pipes for underground drains must possess strength to withstand the pressure of the superimposed soil and the weight and jar of traffic Strength is also necessary to resist the internal pressure of gases, though this should not be great if the drainage system is properly ventilated Internal pressure from the accumulation of a large body of water in any length of piping may be considerable in the case of blockage, and might be sufficient to burst fireclay pipes, especially if these contain faults Ground subsidence may put a great strain on pipes, but the likelihood of this occurring depends naturally upon the nature of the soil ꞁ Drain pipes must have a smooth internal face so that the free passage of wast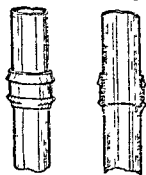e matter is not hindered. A rough internal surface checks the even flow and facilitates the lodgment of solid particles, which then hold back still more, with disastrous results The internal surface must also resist the corrosion of liquids or gases Pipes must be durable, be able to withstand alternating temperatures, the action of chemicals and the friction of sand and other solid particles Absolute impermeability to gases and water is an essential feature without which any drain pipe is not only useless but extremely dangerous, as otherwise the surrounding soil would

Fig 5—Rain Water
Down Pipe

soon become permeated with sewage and sewer gases, thus leading to the likelihood of pollution of wells and other sources of water supply. The shape of drain pipes must be such as to offer the least possible friction to the passing fluids, and therefore round pipes are always used

Since a drain is comprised of a number of joined lengths of pipe, the latter must be so made that perfect jointing can be effected For this purpose one end of a pipe is fitted with a collar into which fits the spigot end The joint is made with material which depends on the nature of the pipe The collar or faucet is at the proximal or inflow end and the spigot fits into the collar of the succeeding pipe

Drainpipes, traps and other fittings are made of glazed stoneware, glazed fireclay or cast iron Stoneware pipes are more brittle and more difficult to cut than fireclay In large pipes, when the flow is strong and continuous, cases have been found where the internal coat of glaze on fireclay pipes has been worn through, but this would seldom happen in house or stable drains

Cast-Iron Pipes. In connection with the drainage of buildings three classes of cast-iron pipes are commonly used. *Rain water pipes* are intended only for conducting the discharge from roof gutters to the ground level. They are of comparatively light metal, and the faucets are not suitable for lead caulking. These pipes should never be used for soil or waste pipes. *Waste and soil pipes* of $^3/_{16}$ inch and $\frac{1}{4}$ inch thickness respectively are cast with care to ensure a smooth internal surface. The sockets are of sufficient width and strength to permit the joint being properly caulked. The pipes are made in 6 feet overall lengths. Cast-iron drain pipes are made of specially heavy design with extra strong sockets. The joint is made with rope yarn and molten lead properly caulked into the annular staving space. This joint is air-tight, and there is little possibility of the leakage of sewer gas. The strength of cast-iron drain pipes, combined with the elasticity of caulked lead joints, enables the pipes and joints to sustain without
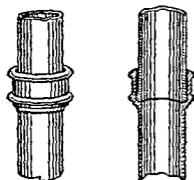

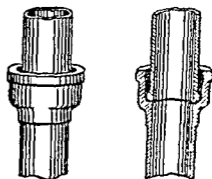FIG. 6.—Soil and Waste Pipe. Staved Joint.

FIG. 7.—Heavy Drain Pipe Staved Joint.

damage subsidence of ground and other accidents which would fracture fireclay or stoneware pipes. Iron drain pipes are made in effective lengths (*i.e.*, exclusive of the depth of socket) of from 3 to 9 feet, the 6 feet length being the most commonly used. As a preventative against corrosion, cast-iron pipes are usually coated inside and out with a bituminous solution.

Comparison between Stoneware or Fireclay and Iron Pipes. The use of cast-iron for drain pipes and fittings possesses some advantages over glazed stoneware or fireclay. Many of the faults found in the latter types are due to bad material and bad workmanship. The laying of stoneware or fireclay pipes undoubtedly calls for more care than for iron pipes. If the pipes are good, free from cracks and faults, the joints properly filled, and the pipes laid in cement concrete where the ground is soft, the result will be satisfactory. Stoneware or fireclay pipes when well laid are always cleaner than iron drains and

will in ordinary circumstances remain practically tight for long periods, on the other hand, iron pipes will remain perfectly tight for long periods but do not remain for any length of time perfectly clean For drains under, or in close proximity to, habitations, iron pipes possess many advantages, especially tightness, and the fact that much better fittings in the way of branches, accesses, bends, traps, etc, can be obtained in iron that in stoneware or fireclay For long lines removed from habitations, the latter are quite good It has, however, always to be borne in mind that, owing to the greater length of iron pipes fewer joints are required than with stoneware or fireclay pipes

Bends As the object of a good drainage system is to convey sewage to the sewer or cesspool as expeditiously as possible and with the minimum of checks on the way, lengths of piping must be laid in as
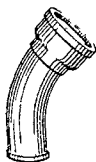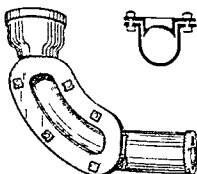

Fig 8 —An Easy Bend.

Fig 9 —An Inspection Bend with bolted cover for iron drain

straight a line as possible Curved pipes called 'bends' are used when abrupt deviations from the straight are necessary and by the use of these specially constructed pipes the flow is checked as little as possible As it is at curves that chokage is liable to occur through the holding up of rubbish which should not have entered the drain, curved pipes are frequently provided with removable bolted covers Inspection chambers fitted with an air tight manhole cover give access from the ground level to the bend

Junctions Where one pipe joins another the junction must be effected so that the inflow of sewage runs smoothly into the main pipe in the direction of the main flow. Junctions at right angles are therefore to be avoided, since a body of sewage so entering strikes the opposite side of the main pipe its own flow is checked and also that of the main current, part of the inflow is turned aside up the main

pipe, and the general stoppage of flow leads to sedimentation through the swirling action with resultant blockage.

Where there are several subsidiary pipes in a system it is advisable that these be laid to converge at a common point so that there may be convenient access to a number of junctions at one inspection
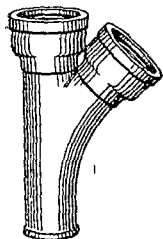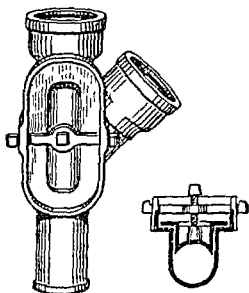

Fig 10 —A " Y " Junction

Fig 11 —An Inspection Junction with bridled cover.

chamber. With modern cast-iron fittings special inspection chambers are made with a variety of junction pipes. Access is accomplished by removing the lid, which is securely bolted down with gunmetal bolts or by means of a bridle. A layer of prepared felt is interposed between the cover and the rim of the chamber, so that the latter is rendered both gas and water proof. If necessary, tributary pipes can be disconnected from the distal drain or sewer at the point of convergence
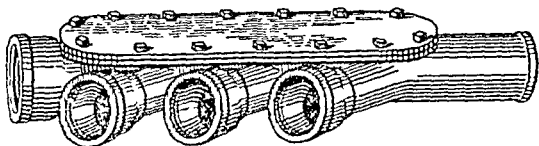

Fig 12 —Inspection Chamber with bolted cover.

by joining the chamber to an intercepting syphon trap, and for convenience in clearing away any obstruction this may be provided with a raking arm as shown in Fig. 13. Access covers for fireclay fittings are bedded down in clay or similar material for easy removal.

The Size of Pipes The size (internal diameter) of drain pipes should be as small as possible consistent with allowance being made for the estimated amount of "drainage to be carried and for possible flooding during heavy rain storms It is very seldom that drain pipes run full bore—probably only in some street drains and then only in exceptional circumstances The more nearly full drain pipes are kept running
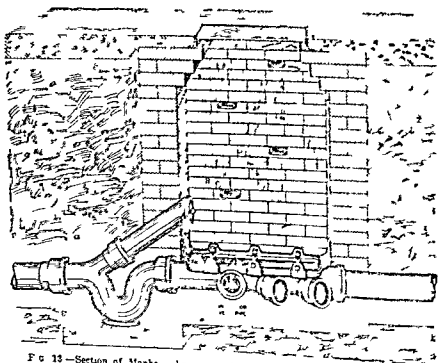

F g 13—Section of Manho sho ng comb na on of nspec o ha ble f on
dra n eep ng rap w h c earng a m on p s and manho e o on

with water or sewage the cleaner they will be and the less chance there will be of silting or blockage occurring

For the drainage from the average stable or cow byre it will be found that a 4 or 5 inch pipe will be big enough

Traps A trap is a contrivance for preventing sewer gas escaping into the house drainage system (an intercepting trap) or for preventing any gases generated in the portions of the house drainage system which convey soil water passing into those portions which convey waste water, or into the build ng (a disconnecting trap)

Since the earliest days of traps the same fundamental principle for olding back gases has been in use namely that of the interpolation of

a body of water in the drain between the sewer and the house or other building. The details of the construction of traps have, however, undergone great modification and improvement and in place of the very insanitary fittings of former days, there are in use to-day traps of simple design which do their work efficiently with the minimum of defects.

The reliability of a trap depends primarily upon the depth to which the in-bent portion of the piping, or lip, dips into the water (see Fig. 14). This dipping-in of the lip constitutes the *seal*, and the depth of the seal is measured by the distance to which the lip dips into the water. If the pipe is not sufficiently bent, or in other words if the lip does not dip sufficiently into the water, a seal too shallow for safety is formed as it may be broken with very little reduction in the volume of water as is indicated in the figure. A satisfactory trap must

effectively prevent sewer gases under ordinary circumstances from passing up the inlet pipes. It must be self-cleansing, so that a moderate influx of water should carry all the trap water before it and leave no sediment behind. It must be of simple structure, have no movable parts and no sharp angles or corners. The internal diameter of a trap should be the same throughout, except in the case of some special forms. It must have a square base so that it can be set firm in the ground without any risk of tilting, with consequent reduction in the depth of water in the seal. The inlets and outlets must be capable of forming perfect joints. An air inlet hole for ventilation must be provided on the proximal or house side,
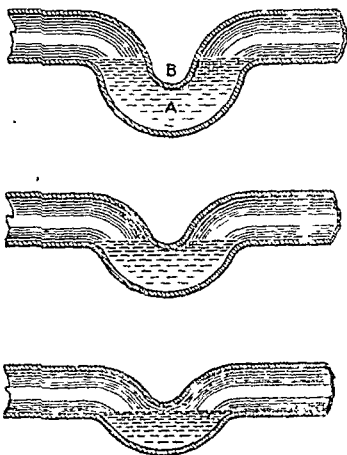

Fig. 14—Three sections of Simple Syphone Traps. The top figure shows a satisfactory seal A-B, the next figure shows a seal that is too shallow, and the bottom section a pipe that is not sufficiently bent to form a seal.

and a hand hole on the distal side for the purpose of removing any possible chokage.

Traps should always be readily accessible. The depth of seal should be such as to obviate any ordinary risk of reduction to danger point by evaporation or waving; a suitable depth is from 2 to 3 inches. The trap should contain just sufficient water to guarantee a safe seal. If the depth of seal is too great, or too much water is retained in the body of the trap, there is a probability that it will not be completely removed with a moderate flushing. It is advisable for the inlet to provide a sudden fall so as to give some impetus to the outgo of sewage, but the outlet should be more gradual so as to render easy the discharge of solids.

One of the earliest forms of intercepting trap is the *dip-stone*, *Mason's* or *built* trap. This is a receptacle built of brick or other mason's material, into which dips a flagstone which is supported by being built into two sides of the structure (see Fig. 15). The dip-stone is supposed to prevent the backward passage of gases into the
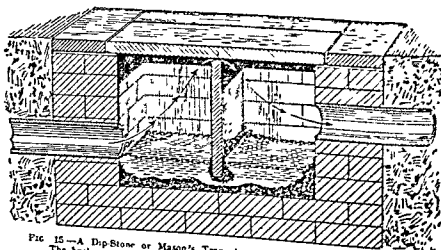

Fig. 15.—A Dip-Stone or Mason's Trap showing the accumulation of sediment. The back passage of sewer gas over the top of the dip stone is indicated by the arrows.

inlet pipe. It is one of the worst forms of traps, and is figured here for the purpose of showing its bad points. Owing to the nature of its formation there is liable to be a settlement of part of the structure with resultant leakage at the top of the dip-stone, and the whole fabric may allow seepage to escape into the surrounding ground. The trap is not self-cleansing, and indeed it is impossible to clean it out thoroughly by any means. The dip-stone becomes coated with organic scum, which decomposes and gives off noxious gases which pass up the inlet pipe. Solids settle to the bottom of the chamber, where they accumulate on both sides of the seal and give rise to continuous putrefaction.

The principles of a modern efficient intercepting trap are exemplified in *Buchan's Intercepting Syphon Trap*. Figure 16 shows that it is provided with an abrupt inlet and a gradual outlet. It might be thought that the water on entering this trap would strike the perpendicular wall facing the inlet and thus check the flow; this, however, is not so because, should the water enter with sufficient force to carry to the opposite side of the inlet, then the pipe would be running full bore and there would be no question of the trap not being completely flushed. Should the pipe be running less than at its full capacity, the sewage would fall over into the centre of the trap, thus forming "Buchan's cascade," the object of which is to break up any scum that may have formed on the surface of the water seal. The seal in this trap is very effective, and the body of water retained is just sufficient to fulfil its intended purpose and is, therefore, completely changed with a moderate flushing. Buchan's intercepting trap, or some modification of it, is in general use to-day for the purpose of completely cutting off the sewer from the house drain. The inlet side of a disconnecting syphon trap is provided with an opening to allow of the free passage of air into both trap and piping, and thus keep the air in the pipe fresh and at atmospheric pressure. This air inlet communicates with the air at or about ground level by means of a length of suitable pipe. At the outlet end of the trap there should be a hand-hole fitted with a lid well luted down with clay or cement in the case of fireclay fittings, or luted with felt and bolted down for iron fittings. This hole provides access in case of chokage, and through it clearing rods can be passed to move on the obstruction.
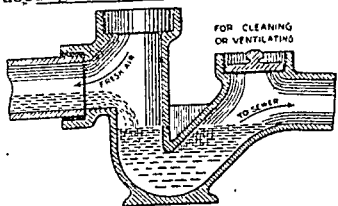

FIG. 16.—Buchan's Intercepting Syphon Trap. Note the abrupt inlet giving a cascade action to the inflowing fluid.

With some traps the hand-hole is extended to form a *raking* or *clearing arm which* makes it more accessible; this is shown in Fig. 17. The hand-hole may also, if required, be used as an outlet for sewer gas, in which case the pipe connected with it is carried above the level of the eaves and well clear of windows.

Gully Traps. With a house drainage system the excreta, together with the soil and waste water, are conveyed away as expeditiously and as economically as possible, the chief object in view being to safeguard

the health of the populace. With animals, on the other hand, both liquid and solid excreta are valuable assets to the farmer, and according to the use made of them the success of the farming may to a large extent depend

The removal of the solid and liquid excreta from animal habitations is effected separately, the liquid portion by means of a drainage system; because of its nature, and its admixture with straw or other bedding material, the solid portion must be prevented from gaining access to the drains, which it would quickly block. Special traps must therefore be used in connection with animal habitations which will let the fluid pass into the drain and at the same time hold back the more solid portion For this purpose gully traps are placed at the inlet of the drains; they are specially designed to catch and retain any solid matter that may be washed into them and which, but for their presence, would be carried into the drain Their usual form is that of a somewhat deep rectangular box with an inlet at the top provided with a grating which is placed at the surface level The invert of the outlet is usually about two-thirds the distance from the bottom of the trap, and the seal is formed by a lip which dips down two inches or so into the water below the outlet level The lip should be so placed as to offer no obstruction to the removal of sediment Many gullies are provided with a bucket to facilitate the removal of the solids These traps are placed wherever the floor drainage from an animal house enters a common drainage system, and also in other places where there is a likelihood of much sediment being carried by surface water, such as in the surface channels at the sides of streets and roads

Figure 21 shows a type of gully trap in common use It is fitted
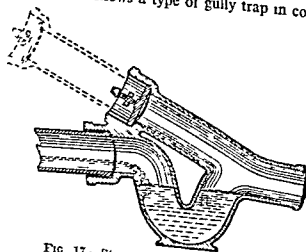

Fig 17—Stoneware Disconnecting Trap with clearing arm extension

with a deep bucket, which is perforated at the top for an overflow into the trap proper and which has an inlet fitted with a deep lip so constructed as to guide solids into the bucket and which, at the same time, acts as a seal of a sort by dipping into the liquid in the bucket This particular type of gully

possesses no real advantage over the more
simple types shown in Figures 18 and 19,
and it is certainly more difficult to clean.

Since the object of any system of
drainage is to remove as speedily as
possible all decaying organic matter, it
will be obvious that any gully trap that
is not self-cleansing, and this none of
them are, can hardly be regarded as a
"sanitary" fitting. The collection of
decaying organic matter gradually decom-
poses, giving off in the process gases
which pass freely into the air. For this
reason no gully trap should be permitted
inside a building, and its location outside
should be away from the vicinity of
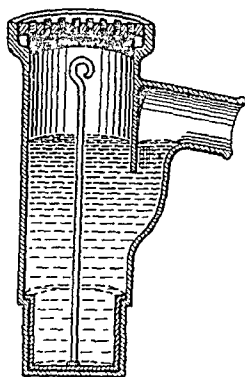doors or air inlets to the ventilation
system.

Fig. 18.—Dean's Gully Trap with
a flat bottom and sediment pan.

As the purpose of a gully trap is merely to prevent much solid
matter from entering the drain, all that is required for this purpose
in stable yards and similar places is a suitable grating to an ordinary
self-cleansing syphon trap. With this idea in view the author has
co-operated in designing the trap shown in Figure 22.

A form of trap which may be found in old drainage systems for
the purpose of trapping surface water or slop waste is the *bell* trap
shown in Figure 23. It is made in two pieces, a lower part which is
the water container, and an upper part which is the inlet grating to
which is attached a lip in the form of a bell or inverted cup which dips
into the water contained in the lower part and so forms a seal. It is
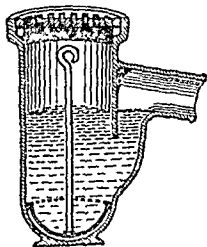

Fig. 19.—Dean's Gully Trap
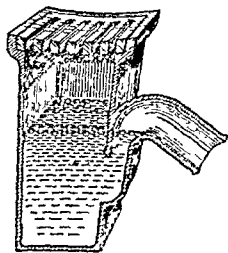with a round bottom and
sediment pan.

Fig. 20.—Road Gully Trap

an inefficient and consequently insanitary form of trap and should never be used   Its most obvious disadvantages are :—the seal is too shallow ; the lip being attached to the grating, the seal is broken each time the grating is removed for the purpose of cleaning the trap and
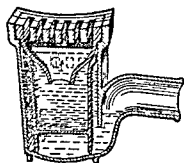

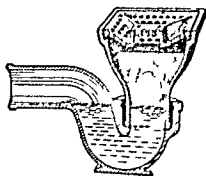FIG 21—A Double Seal Gully with sediment pan

FIG 22—Linton s Gully Top with low back syphon trap

sewer gas can then pass freely into the air , it becomes very easily choked , owing to the shallowness of the water-container the water is soon evaporated in certain situations , the bell is easily broken

THE LAYING OF A DRAINAGE SYSTEM

When laying drainpipes and fittings in a trench care must be exercised to see that the trench has a firm bottom, otherwise subsidence may occur leading to imperfect joints or fracture of the pipes   As a result of this, sewage matter may escape and possibly lead to contamination of a source of supply   If the soil is of a loose character it is well to make a solid bed of concrete for the pipes   Stoneware pipes, especially if running under buildings, should be surrounded with cement concrete

The gradient of the pipes should be such as to ensure a steady and even passage of both fluid and solid portions of the sewage or, in other words, a self-cleansing velocity   For ordinary drains from most

FIG 23—Bell Trap showing the deposit of organic matter

animal habitations a speed of three and a half to four feet per second is satisfactory , this is attained in a 4 inch pipe if there is a gradient of one in forty and in a 6 inch pipe with a gradient of one in sixty if the pipes are running at about one quarter full
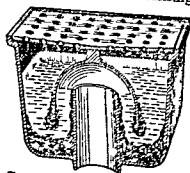
All joints must be made perfectly gas and water-proof, and the material used for sealing the joint must be able to resist the action of fluids from without

and of fluids and gases from within. To make a perfect joint, contiguous pipes must be laid in true alignment and remain so when the jointing material has set. One part of Portland cement and one part of sand makes an excellent jointing material for stone-ware or fireclay pipes. The insertion of a rope gaskin prior to filling with cement is sometimes advocated ; sanitary engineers of experience, however, do not recommend its use as it is apt to protrude into the lumen of the pipe. If the gaskin be of tarred rope it forms a permanent obstruction offering every inducement for the lodgment of solids ; if of untarred rope it soon decays and the joint becomes faulty, sewage collects in the space left by the decayed filling and undergoes decomposition with liberation of foul gases. For iron drainpipes and fittings, molten lead is used as a filling, the spigot of the pipes having cast on it a slight ridge which prevents the gaskin from entering the pipe.

Defects. Defects in drains may be due to several causes :—*(a)* blockage of the pipes or fittings through the entrance of solid objects; *(b)* insufficient gradient, or, conversely, to steep a gradient; *(c)* want of ventilation resulting in the syphonage of traps when a w.c. or sink containing a large quantity of water is let into the drain; *(d)* "waving" of the water in a trap due to alteration in the air pressure of adjacent pipes, usually set up by wind, and resulting in the reduction of the seal; *(e)* infrequent flushing of the drains resulting in reduction of the seal in traps by evaporation; *(f)* imperfect laying of traps so that these become tilted out of line, so reducing the depth of the seal; *(g)* bad workmanship in laying drains, such as imperfect alignment and the access of cement into the pipes at the faucet during the joint making; *(h)* inspection covers not made air-tight; *(i)* using pipes which are too large or too small; *(j)* imperfect ventilation of lengths of piping, so that sewer gas accumulates under pressure and forces the water seal of a trap; *(k)* imperfect flushing of the system with the result that solids accumulate and gases generate; *(l)* subsidence of the soil with consequent sagging and rupture of pipes or their joints; *(m)* use of unsuitable substances, such as clay, for jointing material; *(n)* too many bends in a system, or these improperly made; *(o)* junctions not effected at a suitable angle.

The Testing of Drains. Drains must be tested after laying to ensure that they are gas and water tight, and that the water seals of the traps are satisfactory. Tests are carried out on the various sections of a drainage system during its construction, and a final test on the whole system when completed. Thereafter, periodical tests should be made from time to time to ascertain that the system remains satisfac-

factory, as defects may develop from various causes which, if not rectified, may cause serious pollution

The methods of testing drains are described below :—

The Air and Smoke Tests. The air test consists in plugging the open ends of the drains and ventilating pipes and then pumping in air under a pressure sufficient to be indicated on a pressure gauge If the gauge does not show that a fixed pressure is being maintained, this denotes a leak or leakages These can generally be located by filling the pipes with dense white smoke, afterwards plugging the pipes and applying the same pressure as before This will force the smoke out at the defective parts and enable them to be located and made good. This test should be continued until the gauge remains steady and proves that the drains are sound Under normal conditions there is little or no pressure inside the drainpipes, so that an air-pumping apparatus that will give about $\frac{1}{2}$ oz pressure per square inch will apply a sufficient test both to the drains and to the trap seals A one inch head of water represents 0 577 oz per square inch, and as the seal for small traps is usually $1\frac{1}{2}$ to $1\frac{3}{4}$ inches they should be able to stand a test of $\frac{1}{2}$ oz pressure The best apparatus for applying the air and smoke tests is a combined air and smoke testing apparatus, which can be used for either or both tests as outlined above

The Hydraulic Test. In the hydraulic test the outlet of a drain, or a section of it, is plugged with an expanding rubber bag, or other patent stopper, and the section to be tested then filled with water to a pressure equivalent to a head of from 6 to 10 feet The water is left in for two or three hours, and if a leak exists its presence will be indicated by a fall in the head of water at the point of observation

SEWAGE DISPOSAL

Sewage consists of a mixture of solid and liquid human excreta, waste water from dwelling houses, and usually rainwater and road washings ; it may also contain a greater or lesser amount of trade wastes The disposal of sewage in a manner which will be free from nuisance and danger to public health through contamination of water and food supplies is a matter of great importance in connection with food (including meat and milk) control and inspection

It has frequently been alleged that the drinking of water polluted by domestic sewage has given rise to symptoms of poisoning in cattle and other animals (see pp 64-65) On a number of occasions complaints on this score from farmers have been pressed with success in the Courts Since veterinarians may be called upon to give evidence

as expert witnesses in such cases, an outline is given below of the methods of sewage treatment and disposal.

The methods of sewage disposal may be divided broadly into the *Conservancy* and the *Water Carriage* systems.

Conservancy Method. In this method, sewage is dealt with intermittently after storage for some period. It is now practically confined to rural areas where the water supply is inadequate for the installation of a water carriage system. The simplest method of disposing of human excreta, and, with the exception of chemical treatment, the only method where there is not an adequate water supply for water carriage, is burial in the soil. To the veterinary hygienist particularly concerned with milk production the proper disposal of such material is of some importance, owing to the risk of flies carrying pathogenic bacteria, such as typhoid bacilli, from infected excreta to the milk. If voided into a pail, the excrement should be covered by dry soil (which is the best material), ashes or sawdust, and thereafter be properly buried, not deposited on a manure heap as is sometimes done. Disinfectant should not be added to the pail contents, unless the object is complete liquefaction of the faeces by chemicals, because in most cases disinfectants and antiseptics merely retard putrefaction; once buried in shallow trenches and covered with topsoil without chemicals, the faeces soon decompose without causing any harm. The place chosen for the ultimate deposition should be distant from the house and not near a well. Where human excreta is disposed of by the dry method there still remain to be dealt with the waste waters from washing and other domestic operations. These may be disposed on garden ground, either directly or in a soak-away pit.

Water Carriage System. In this system the private drains from dwelling-houses and other buildings empty into public sewers, which convey the sewage to a purification works where it is treated so as to render the resulting effluent suitable for ultimate disposal into the sea, or into rivers and streams.

The history of sewage disposal shows that originally the method adopted was discharge of the untreated sewage into the nearest stream or into the sea. Where populations were large and the streams available small, intolerable nuisance arose, and Royal Commissions were set up to consider the subject of sewage disposal and rivers pollution prevention. Following on the report of the Rivers Pollution Commission of 1868, the Rivers Pollution Prevention Act of 1876 was passed in order to put a check on unrestricted pollution of rivers. Although amendments of this Act have been proposed from time to time, it is still in operation.

The Salmon and Freshwater Fisheries Act, 1923, also places restrictions on the discharge of sewage into tidal waters or into streams.

Composition and Strength of Sewage. In the fifth report of the Royal Commission, sewage is defined generally as "a mixture of saline matter in solution and nitrogenous and carbonaceous organic matter in solution and suspension together with a certain amount of grit and mineral matter" The strength of an ordinary domestic sewage depends on the amount of water used per head of population If there are industrial wastes the strength will usually be increased. There are, of course, great variations—daily, seasonal and those due to storm water Industrial wastes, such as those from breweries, gas works and dairies, etc., introduce additional complications

Chemical analyses of sewage usually indicated in parts per 100,000 : (1) The solids in suspension and in solution, (2) organic nitrogen—ammonical and albuminoid, (3) chlorides; and (4) quantity of oxygen required for oxidation of the organic matter to produce a non-putrefactive effluent The Royal Commission in the standards recommended for Sewage Work Effluents have adopted the solids in suspension and the dissolved oxygen absorbed in five days The latter is sometimes referred to, particularly in American books, as the Biochemical Oxygen Demand (B O D)

The total solids in suspension measured dry in a typical sewage where the dry weather flow is about 30 gallons per head taken as one part in 2500 by weight, that is, less than one-fifteenth of an ounce per gallon The settling solids will be about two-thirds of the total About three-fourths of the total suspended solids would be organic The non settling solids are in a very fine state of division or in colloid form The total suspended matter appears to be very small, but when considered as sludge in the condition in which it requires to be abstracted from the sewage and handled, it becomes more formidable, and will be considered later

It seems safe to assume that if any particular river or stream water is not polluted to a greater extent than allowed for in the Commissioners' suggested standards, that the water would be harmless for stock Pollutions with trade, factory and pit wastes are, however, different matters, and each offers a distinct problem to the veterinary hygienist when he is asked to express an opinion regarding the possible deleterious effects of industrial effluents on livestock That these effluents may be harmful, experience has shown to be the case (See page 65)

DISPOSAL OF WATER-CARRIED SEWAGE BY DILUTION

DISCHARGE INTO THE SEA. This is an obvious method for the disposal of sewage from coastal towns. The following points are taken into consideration —The state of the tides, action of discharging rivers, and the influence of prevailing winds tending to carry the sewage to the foreshore ; the possible de-

Ίeterious effects of the sewage on boating and bathing ; the pollution of the beach by the deposit of solids ; the possible injury to fishing, and the possible infection of shell-fish by sewage contaminated with pathogenic organisms such as typhoid bacilli.

The sewage is either discharged in its crude state into the sea, or after it has been screened and treated in a settling tank, but unless the position of the outlet and the tidal flow are particularly favourable, further preliminary treatment is usually carried out. In some cases tanks are used to store the sewage during the rising tide and to enable discharge to take place during the ebb tide only. As a method of purifying sewage, screening is not very effective, particularly if the sewage has travelled through several miles of pipes, because by the time that it has arrived at the screen it is already in a state of emulsion, the solids having become disintegrated, but not reduced, while passing through the pipes.

DISCHARGE INTO RIVERS. Where the stream is large enough to give a dilution of over 500 volumes, the crude sewage may be discharged into the stream "subject to such conditions as to the provision of screens or detritus tanks as might appear necessary to the Central Authority." For example, pre-treatment of the kind specified may be required for the sake of amenity or to prevent the formation of sludge beds.

PURIFICATION TREATMENT OF WATER-CARRIED SEWAGE

The objects of a sewage purification works are :—

    (a) To separate the solids and suspended matter, which are for the most part putrifiable, from the fluid portion ;

    (b) To purify the fluid portion, so that it can be ultimately discharged into a river or stream with safety and without causing a nuisance ;

and (c) To dispose of the more solid portion of the sewage which becomes settled out to form "sludge."

Before any particular system of treatment is adopted, the local conditions must be thoroughly studied with reference to the amount and character of the sewage. These will be found to vary considerably, depending on whether the town is a residential or an industrial one. Sewage from a purely residential town with a good water supply is comparatively easy to treat ; that from a manufacturing town with a less generous water supply and with the inclusion of industrial wastes presents far more difficulty.

The volume of sewage is usually stated in gallons per head of population per day ; this may vary from about 10 gallons up to 100 gallons or even more, depending on the water supply available and the habits of the community under consideration. A common figure for daily dry weather flow is 30 to 40 gallons per head.

Sewerage systems of towns may be on either the *separate* or *combined* system. In the first mentioned, separate sewers are provided for sewage and for rainwater from roofs, streets, etc. In the combined system, rainwater and sewage are carried in the one sewer. The latter method is the more common, and where it is adopted the quantity of sewage to be dealt with is, of course, greatly increased in wet weather.

The processes to which water-carried sewage is submitted at the average purification works may be classified under the following headings :—

A. PRELIMINARY TREATMENT.

    1. Arrangements for dealing with Storm Water.

    2. Screening.

    3. Detritus or Grit Tanks.

    4   Sedimentation or Precipitation Tanks
    5   Disposal of Sludge
B TREATMENT OF TANK LIQUOR
        Land Treatment, or
        Artificial Biological Treatment
            (a) Percolating or Trickling Filters
                or   } followed by Humus Tanks.
            (b) Contact Beds

In some large towns, e g Manchester, Sheffield, Bury, Birmingham, etc , a method known as *Biocration* or the *Activated Sludge System* has been adopted

PRELIMINARY TREATMENT

1 STORM WATER Since the combined system of sewerage is in more general use than the separate system, provision has usually to be made for an excessive flow of sewage during periods of rain The Sewage Commissioners recommended that an increase of sewage up to three times the dry weather flow should be dealt with in the works as ordinary sewage Anything over this amount should be diverted to special storm tanks, from which it can be later dealt with

2 SCREENING This is necessary to remove gross solids such as lumps of faeces, paper, etc. The process may consist of *coarse* or *fine* screening In the former method the sewage is passed through fixed screens made of vertical iron bars, which are one-half to 2 in apart. In the larger works the screens are scraped and cleaned by machinery These screens may remove as much as 10 per cent of the total suspended matter in the sewage Fine screens are of various types the openings being from 0 2 to 0 3 in. wide they are usually cleaned by brushing or by a jet of water Fine screens are not used in this country but at one time this method was the only treatment in use in New York, it was found to be unsatisfactory and further treatment by the Activated Sludge System has been adopted

3 DETRITUS OR GRIT TANKS These are intended to remove the heavier inorganic matter, such as road grit, which is easily settled They are usually made of comparatively small capacity say about two hours of the dry weather flow, and are constructed so that they may be readily cleaned They relieve the load on the sedimentation tanks

4 SEDIMENTATION OR PRECIPITATION TANKS These are tanks usually built of concrete which may be worked with or without the addition of chemical precipitants and in which the finer solids in the sewage are allowed to settle by sedimentation the resultant precipitate or sludge, is pumped out daily or weekly as may be found necessary in practice

    Tanks may be operated on the fill and-draw method or on the continuous method In the former the top liquid is drawn off by a floating arm or other device, leaving the sludge to be cleaned out and dealt with separately

    Continuous flow tanks may be designed for horizontal flow or vertical flow The design varies also according to the method of drawing off the sludge proposed to be adopted

    Horizontal flow tanks are usually long in relation to the width, the proportion being 3 to 1 or 8 to 1, and are relatively shallow Where the bottom is flat the sludge may be removed after the removal of the supernatant liquid, by machinery, in which case the tanks are circular or square with rounded corners. An alternative method is to have one or more inverted pyramidal or conical hoppers constructed in the floor The sludge is abstracted from the bottom of the hopper by having the outlet at a level which gives a sufficient head of sewage.

Upward flow or Dortmund tanks are deep and have hopper bottoms. The sewage is made to enter at the centre and deflected in a downward direction by tubes or boxes, the outlet for the clarified effluent being at the top edges

The capacity of a sedimentation tank is usually fixed to give a period of detention of 6 to 8 hours in the tank, based on dry weather flow, so that the settle sewage may be passed on in a comparatively fresh condition

Chemical precipitation of the suspended matter is adopted where the sewage is very concentrated or where trade wastes have to be removed. Lime, or lime and ferrous sulphate, or sulphate of alumina are used as precipitants The amount of sludge produced by the aid of precipitants is greater than with simple sedimentation

5 DISPOSAL OF SLUDGE One of the most troublesome parts of sewage treatment is the disposal of sludge, including screenings and detritus Although the total amount of solids measured dry are small, the sludge as drawn off from the various processes may contain anything from 90 to 98 per cent of water, it will thus be seen that the quantity to be handled is considerable On the basis of a 30 gallons per head sewage, the quantity of sludge containing 95 per cent water might approximate to 2 lbs per head per day This gives about 9 tons per day for a population of 10,000 or 3000 tons per annum The quantity from septic tanks where some digestion takes place would be about half this amount. With quiescent chemical precipitation the quantity would be about 50 per cent. greater. On the other hand, surplus activated sludge, which may contain as much as 98 5 per cent of water, would be about five times the amount

Screenings and detritus are always very offensive, and are usually dealt with by shallow burial In the case of large cities sometimes screenings are burnt The methods of disposal of sludge vary according to the situation and size of the town Several large cities, such as London, Glasgow, Manchester and others, discharge all surplus sludge into the open sea

Where sea disposal is not possible, disposal on land is resorted to, either direct or after partial dehydration Where direct disposal is adopted the sludge is pumped on the land, and, after drying, is ploughed in

Sludge has considerable manurial value, but before it can be handled the water content must be reduced This may be done on sludge filter beds, where the sludge is spread on comparatively thin layers of porous material, such as ashes well underdrained In some cities the sludge may be pressed into cake and afterwards converted into manure

Sludge may be digested in deep tanks, during which process a considerable amount of gas is given off, consisting chiefly of methane with a small proportion of carbon dioxide and hydrogen In the most recent installations these gases are collected and utilised for power purposes It is reckoned that with efficient digestion, sufficient gas may be obtained for the power requirements of the sewage works Digested sludge contains, of course, considerably less organic material than the original and is non-putrefactive It may be used for raising the level of low lying areas of land without causing any offence In some cases the digested sludge is used as a base in the manufacture of artificial manure

Septic Tanks. In all forms of tank treatment, in addition to the deposition of sludge, a large proportion of the organic matter is rendered soluble by putrefaction or "septic" action which, for the most part, proceeds anaerobically. If sewage were held sufficiently long in a tank, the greater proportion of the organic matter would

pass into solution and little or no sludge remain Such a tank would then become a "Septic Tank" The difference between this and a sedimentation tank is very largely a difference of size in relation to the daily volume of the sewage and a difference in the way in which the sewage enters and leaves the tank In septic tanks the size of the tank is large in proportion to the flow of sewage, the sewage enters and leaves the tank below the surface of the liquid in order not to disturb the scum which forms and sludge is removed as seldom as possible In sedimentation tanks a smaller number of hours' flow is provided for, no attempt is made to encourage the formation of a scum, and removal of the sludge is frequent It is evident that putrefaction will proceed more vigorously in septic tanks than in sedimentation tanks, and also that if the sludge is not frequently removed from sedimentation tanks they will function to some extent as septic tanks In actual practice it is found that from 20 to 40 per cent of the organic matter may be digested in septic tanks, with the formation of large quantities of gases, chiefly methane Septic tanks constitute a suitable means of sewage treatment for single houses or for small communities, provided that not too much inorganic solids are carried in the sewage

TREATMENT OF TANK LIQUOR

In the great majority of cases the liquor from the tank treatments requires further purification, although under certain circumstances where the volume of a stream receiving sewage effluent is very much greater than that of the effluent, further treatment will not be necessary (see recommendations of the Royal Commission on Sewage Disposal)

Land Treatment is the oldest method of dealing with tank liquor The best soils for the purpose are light and porous with a subsoil of gravel and sand, clay and peat are not satisfactory Chalk is dangerous in certain areas, on account of the possibility of pollution of water supplies through faults and fissures in the stratum. The following methods of using land are practised

(a) *Sub-soil Irrigation.* Frequently adopted in small installations By this method the overflow from the tank is led into open-jointed drains of sufficient length, laid at a flat gradient, so that the tank effluent is allowed to soak away over a comparatively large area

(b) *Broad Irrigation* The sewage is distributed over a large area, usually of grassland, having a slight slope, the suspended matter being strained out and acted on by the soil bac-

teria. Disposal in this way is sometimes known as the "Sewage Farm" method.

(c) *Land Filtration.* In this case the land should be fairly level and well under-drained, the soil being of a very porous character. The sewage is allowed to flow on to this to a depth of three to six inches. It is oxidised in the process of filtration through the soil. In some cases the land is cultivated in the ridge-and-furrow system, plants being grown on the ridges and the tank liquor distributed along the furrows.

In all the land systems considerable periods of rest are necessary, and therefore the sewage must be applied intermittently. Wells should not be situated near to land used for the purification of sewage, nor should water for domestic or dairy purposes be taken from a stream in the neighbourhood of the irrigation area.

Artificial Biological Treatment.

Percolating or Trickling Filters are really aerating beds, not filters ; they consist essentially of circular beds of broken stone of various sizes on which sewage is distributed. (See Fig. 25.) The broken stone becomes coated after a short period with a gelatinous covering which, in the presence of oxygen, forms a nidus for aerobic bacteria which is then said to be "ripened" or "activitated." Distribution of the tank liquor is obtained by means of a revolving sprinkler driven by a constant head of water, or by the intermittent discharge of a siphon.

Contact Beds comprise tanks filled with clinker or broken stone, the object being to permit digestion of the organic material by aerobic bacteria. The tank is filled and the liquor allowed to remain in contact with the material in the bed for a sufficient period to allow purification to take place ; thereafter the tank is emptied, and in the process air is drawn into the interstices of the clinker, thus providing the oxygen necessary for the bacteria. The cycle of operation occupies eight to twelve hours, the resting period being about half this to keep the beds in condition. Contact beds are not now being installed, as percolating filters are regarded as being more efficient.

Humus Tanks. The effluent from percolating filters and contact beds often contain a good deal of fine organic matter termed "humus." It is necessary to allow this to settle before discharging the final effluent into a stream. This may be done by holding the filter effluent in tanks of a capacity equivalent to about two hours' dry water flow.

Fig. 26.—Typical Plan showing the general arrangement of a complete Bio-æration System. No indication is given as to the method of aeration, whether by compressed air or mechanical agitation, but the tailed arrows indicate the flow through the several tanks.

puddled clay, having the bottom open so that the liquid percolates into the soil ; this type of cesspool is thus a soak-away pit, and it is obvious that to be effective it must be situated in a sufficiently porous sub-soil. The construction is illustrated in Figure 27. The soil pipe before it reaches the cesspool discharges into a disconnecting syphon trap fitted with an air inlet on the proximal side ; the pipe discharging into the cesspool dips down into the sewage, and in the case of a pervious cesspool there should be a slab of slate, brick or concrete directly under the influent to prevent the incoming sewage from wearing away the ground from the foundations. The impervious cesspool differs from the foregoing in that the bottom, as well as the sides, is made of impervious material, through which nothing can percolate.

Under powers given by the Public Health Act, 1936, no Local Authority will now permit the use of a pervious cesspool, other than as a soak-away for rain or surface water.

In both types of cesspool, decomposition of the sewage, which is effected by bacteria, is incomplete, so that there is a continuous accumulation of partially decomposed, evil-smelling material which has to be removed periodically. During the process of decomposition, objectionable gases, including large volumes of sulphuretted hydrogen, are given off. In the pervious cesspool, comparatively little material accumulates ; with the impervious type, frequent emptying is necessary. In the case of single houses or farms it is a common practice to provide an overflow drain, the liquid being disposed of by irrigation over land or by sub-surface irrigation by connecting into an open-jointed agricultural drain. When no overflow is provided the whole of the liquid requires to be pumped out and disposed of as often as is necessary. Many Local Authorities in rural areas now undertake the removal of cesspool sewage in specially equipped motor tankers.

Provided a cesspool is properly constructed and looked after intelligently, and is drained away from dwelling-houses, from which it should be at least one hundred feet distant, and is not placed in proximity to a well or other water supply, there is no objection to its adoption in isolated situations where the volume of sewage to be disposed of is not likely to be great. Instances have occurred, however, where the contents of the cesspools have saturated the surrounding soil, or where sewage in a fresh state has overflowed on the surface ; in such cases there is a considerable risk of the contamination of wells, or of flies spreading disease, especially typhoid. Gair,* in recording an outbreak of diphtheria transmitted by milk, suggested that the

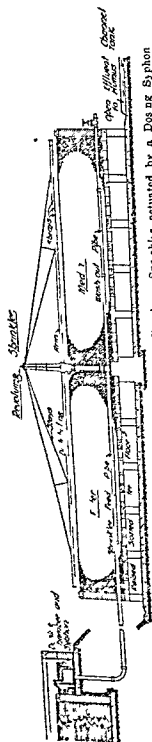*Gair (1918), *Vet. J.*, *LXXIV.*, 447.

Fig. 24—Typical Section showing a small Percolating Filter with Revolving Sprinkler actuated by a Dosing Syphon
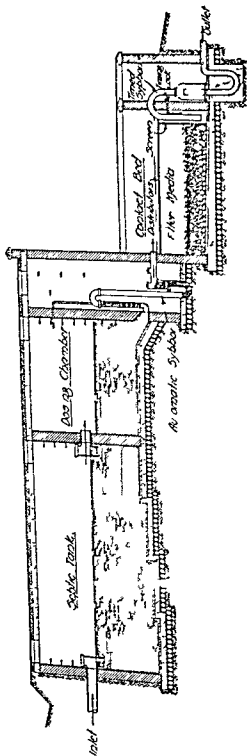

Fig. 25—Typical Section of a small Sewage Installation comprising a Septic Tank and a Contact Bed

Bioaeration or Activated Sludge Process. In this method screened sewage, free from detritus, is purified in tanks largely by aerobic bacterial action. (See Fig. 26.) The bacteria are attached to the particles of ripened or "activated" sludge which is mixed with the incoming sewage, and the mixed liquid is kept in continuous motion during its passage through aeration tanks, in order firstly to prevent settlement of the sludge, secondly to bring the organic matter in contact with activated sludge, and thirdly to supply the bacteria with oxygen. Skilled management is essential for the efficient operation of a bioaeration plant. It was at one time thought that the activated sludge process would supersede all other methods of sewage purification, but experience has shown that the best and most economical system is to use the process in association with settlement tanks and filters. In Birmingham, for instance, aerating tanks have been placed between the settlement tanks and the percolating filters, with the result that two or three times the amount of liquid can now be dealt with by the filters than was formerly the case.

Chemical Sterilisation of Sewage Effluent. Pathogenic bacteria, *e.g.* typhoid and paratyphoid bacilli, have frequently been isolated from sewage and sewage effluents. With a view to rendering tank liquors innocuous, particularly where the effluents are discharged into streams which later in their course are used as sources of water supply, experiments have been carried out to determine the dose of disinfectants, such as pure chlorine, bleaching powder and "Chloros" (containing 10 per cent. available chlorine). In the case of an ordinary sewage, it has been found that these would have to be added in the proportion of at least 10 to 15 parts of available chlorine per million parts of sewage to effect any marked reduction of the *Bact coli* present ; in addition, a long period of contact would have to be allowed. Such practice would add materially to the cost of sewage purification and it has not, therefore, been adopted in this country. It might be useful in the event of outbreaks of epidemic disease such as typhoid or paratyphoid.

SMALL SCALE SEWAGE PURIFICATION AND DISPOSAL

Where no public sewer is available, other methods such as the impervious cesspool or a septic tank installation must be adopted for the disposal of sewage.

Cesspools. Cesspools of two kinds may be met with—*pervious* and *impervious.* The pervious cesspool is a chamber built of concrete or brick or stone, rendered in cement, and surrounded if necessary by
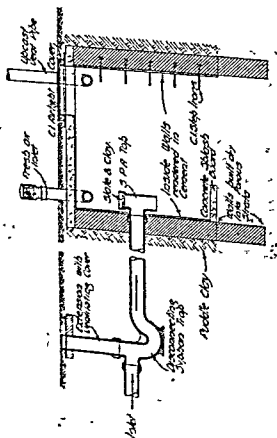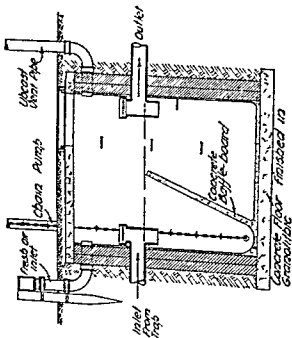
FIG 27.—Typical Sections of Pervious and Impervious Cesspools,

diphtheria organism may have been carried by flies from an overflowing sewage tank to the milk.

Septic Tank Installation. An installation suitable for the purification and disposal of sewage from isolated buildings usually comprises (i) a simple form of septic tank, designed to retain the sewage for a period of time sufficient to permit anaerobic digestion of its organic solids and to allow insoluble matter to settle out as sludge, and (ii) a percolating filter or a contact bed in which the effluent from the septic tank is purified by aerobic bacterial action. (See Fig. 25). The final effluent should be fit for discharge into a stream or for disposal by subsoil irrigation without any potential risk arising. Rain and other surface water should not be allowed access to a septic tank, but a drain conveying this water may with advantage join the outlet from the aeration bed. The sludge needs removal only at long intervals, extending in some cases to as long as two years.

REMOVAL AND DISPOSAL OF EXCRETA AND OTHER WASTES FROM ANIMAL HABITATIONS

A proper system for the hygenic disposal of animal excreta is essential for the preservation of animal health and as an aid to the control of disease. The disposal of excreta, together with the straw or other material used for bedding, is complicated by the fact that this material has a considerable manurial value, and usually has to be conserved or stored in some way until it can be conveniently applied to the land. The elaborate and expensive systems of sewage treatment adopted in local government undertakings are clearly not capable of adaptation to animal habitations ; the problem therefore, in livestock sanitation is to secure the disposal of animal manures in as simple and as practicable a manner as possible, and so that they do not serve as a vehicle for the propagation of disease or become a source of public nuisance.

The systematic collection and storage of animal manure involves :

(1) The collection of faeces and soiled bedding, i.e. the solid manure, and its removal from the stable, cowshed, or other building.

(2) The storage of the solid manure so that its potentially disease-bearing state is rendered innocuous, whilst at the same time its land fertilizing capacity is conserved.

(3) The conveyance from the building of voided urine, and such solids as pass with it, to an outside drainage system.

(4) The disposal or conservation of the liquid manure.

THE COLLECTION AND STORAGE OF THE SOLID MANURE

Removal of Manure from Buildings   The collection of solid manure in animal habitations under ordinary management is usually carried out once or twice daily   Removal from the building is usually effected either by means of a wheelbarrow or similar vehicle or often by simply throwing the manure through an open door on to a dump situated immediately outside the buildings   From the hygienic point of view, a serious objection to this latter method is the close proximity of the dung heap to the buildings   The old fashioned wooden wheel barrow and the more modern open trolly also invite criticism , in most instances they are very unsuitable receptacles for conveying long strawy manure from stables or for removing semi liquid excreta from cowsheds since these materials get scattered or spilt and give rise to unnecessary filth on yards and roadways   Where a barrow has to be used, it should be made of metal and have widely sloping sides so that is easily retains the manure placed in it   being of metal it can be washed and disinfected periodically   Where the size of the buildings and the number of animals kept are sufficiently large to justify it, the better method is to drive a horse (or tractor) and cart (the latter preferably constructed of or lined with, metal) into the dunging passage of the buildings so that the manure can be placed directly into the cart for removal   Where buildings are not adapted for the entry of a manure cart an alternative method which makes for labour saving is to build a concrete loading ramp of tailboard height at one end of the building   Barrows loaded with manure can be easily wheeled up this ramp and emptied into a cart at the loading face of the ramp

In modern dairy cowsheds a galvanised steel tub, with a capacity of approximately 12 bushels (size 48" long × 22" deep × 27½" wide) fitted with an overhead track system of runways extending through the cowshed and out to the manure dump, is now commonly installed , effects a considerable saving of labour the cowshed and out to the manure dump, is now commonly installed , such an appliance fulfils all hygienic requirements and, in addition,

Manure Pit   The manure pit should be sited as far from the buildings as can reasonably be arranged, having regard to the labour involved in transporting the manure from the stable or byre   This is especially necessary in the case of cowsheds and dairies   not only as a safeguard against smell, but also as a preventive measure against the nuisance of flies   Fresh manure forms an ideal breeding ground for the common house fly (*Musca domestica*) a pest which may easily become a hindrance to clean milk production   Flies also cause considerable annoyance to the cows in summer, and there is some evidence that they

may be a factor in the spread of mastitis. *Every precaution should, therefore, be taken to lessen these risks.*

The common practice of depositing the manure in a dump immediately outside the buildings, and into which the drainage system empties, is most objectionable; this site is usually dictated by the arduous task of removing manure from a building by hand barrows, and by the scarcity of man-power; the problem may best be overcome by the installation of the overhead carrier system, mentioned above. A concrete pathway should connect the buildings and the manure pit and, where it is possible, accessibility to the latter from a hard road is an advantage when it comes to transferring the manure to the land.

In estimating the space likely to be required for a manure pit or storage dump several factors have to be taken into consideration. These include the number and species of animals kept, the nature of the food consumed, the amount of bedding supplied and the extent to which it is re-used or discarded, and the length of time the manure is to be stored.

In connection with this last point, it should be noted that under the Public Health Act, 1936 (Sections 72-82), an urban Local Authority has the power to "call for the periodic removal of manure from mews, stables or other premises." The Local By-laws should, therefore, be consulted with regard to the regulations in force regarding the disposal of animal manure from town premises. It may be noted that the Model By-laws, 1937, recommend that structures in which horses, cattle or swine are kept must be adequately drained and provided with suitable receptacles for filth. The bottom of the receptacle must not be below ground level, and the receptacle must have a suitable cover, must be emptied at least once a week and must be so constructed and maintained as to prevent escape of its contents. These provisions apply in a rural district only to a structure within 60 feet of a dwelling-house not being the dwelling-house of the occupier of the premises. London County Council By-laws provide that "No dung-pit shall be adjacent to the walls of any human habitation and the pit shall be so made that a part of one side can be removed for ready cleansing of the interior," and that "No dung-pit shall have a capacity of more than 2 cubic yards unless it be emptied every 48 hours." In the case of cowsheds the Milk and Dairies Regulations, 1949, Article 15, requires that every dairy farmer shall "cause all dung and other offensive matter to be removed at least once every day from any milking house in his occupation and cause the approach and access to any milking house or milk room to be kept free from any accumulation of dung or offensive matter."

On farms in country or rural areas hygienic and other considera-

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tions demand that manure heaps be cleared at regular intervals, and with this end in view, therefore, the size of a permanent or fixed installation for the storage of manure should be related to the number of animals kept. It is suggested that a manure pit should be of such a size as to ensure that it must be emptied every 6 to 8 weeks. In the case of farms the amount of bedding mixed with the excreta is likely to be relatively small, and what there is will probably be well broken down. In establishments where the cleanliness and appearance of the animals are the first considerations, it is possible that the amount of bedding discarded will equal in quantity or even surpass the amount of real manure which has to be dealt with. The bedding, too, being comparatively fresh, retains its elasticity and bulk, and thus occupies relatively much room in the manure pit. Under such conditions it may be found advisable to have the manure separated from the bedding, which can be dried for further use or finally disposed of separately. While keeping in mind the many factors which tend to cause more variation in the quantities of manure the following figures which were arrived at by Smith* will be found useful as a guide :—"In an experiment carried out for several months with different horses all receiving 12 lbs. hay and varying proportions of bran and oats the average daily amount of faeces weighed in its natural state, amounted to 24 lbs. In the ox the amount of faeces is between 70 lbs. and 80 lbs. in the 24 hours. In the sheep the faeces vary from 2 lbs. to 6 lbs. daily, in swine 3—6 lbs. depending upon the nature of the diet." Patton† also states that a horse produces about 2 cu. ft. of manure daily.

In calculating the capacity of a permanent pit suitable for storing manure from dairy cowsheds, it has been found that a space of 1½ to 2 cub. ft. per beast per day will usually meet all requirements.

The actual constructional details of storage pits for manure may vary widely according to the nature and situations of the establishment, local material available, the cost involved, etc., but with regard to ordinary farm premises the under mentioned principles should be followed :—

1. Retaining walls, about 4 to 5 ft. high, preferably of brick or concrete.

2. Bottom should always be impervious ; cement concrete is the best material ; there should be a fall to one end, where a drain leads to the liquid manure tank.

*Veterinary Physiology, Smith, 1895.

†Insects, Ticks, Mites and Venomous Animals of Medical and Veterinary Importance, W. S. Patton, Pt. II., 1931.

3. The liquid manure tank should never be under the floor of the manure pit, because of the inaccessibility of this position.

4. The manure pit should be roofed over with galvanised iron or other suitable material to prevent the leeching of the valuable soluble constituents—nitrogen, phosphates and potash—from the manure. The roof must allow free circulation of air over the manure, otherwise the latter may get too "hot," and so deteriorate.

In the "making" of stored manure, proper conditions are essential if its optimum fertiliser capacity is to be developed. This process involves anaerobic bacterial action, which proceeds at its highest level in the absence of oxygen and when sufficient moisture and warmth are present. These requirements are satisfied when the manure mass is tightly packed, so that excessive oxidation and evaporation are prevented and the heat arising from bacterial action is conserved. Fortunately, these conditions, essential for the making of good manure, also serve to prevent the multiplication of flies and to bring about the destruction of certain pathogenic bacteria and strongyle and other worm larvae.

In certain circumstances, manure may be carted direct from the animal buildings to the land without any period of storage intervening. There can be no objection on hygienic grounds to such a method of disposal, provided the manure is to be spread on arable land or on fields not being used for livestock. Faecal material deposited in this way, as well as that voided by the animals themselves when at pasture, may remain potentially infective with the organisms of tuberculosis, Johne's disease and with parasitic ova and larvae for considerable periods.

The Conveyance of Liquid Manure from Animal Buildings

The removal and disposal of urine and other organic liquid wastes from animal buildings calls for some form of drainage system, which, in essentials, should be of a comparatively simple nature compared with that of human habitations. The interior drainage arrangements in modern animal buildings of proper design consist merely of surface channels, which conduct the liquids to a proper outlet-drainage system. The dimensions and arrangement of the surface channels are closely bound up with the details of floor construction, and also with the species of animal concerned, and can more conveniently be dealt with under the construction of the building as a whole. (See appropriate parts of Section IV., HOUSING OF ANIMALS.)

The surface channel, or channels, inside the building discharge through an opening in the wall at ground level into a suitable gully

trap ; it is sometimes advised that the wall opening should be fitted with flaps or baffles so that it does not give rise to a direct draught on the nearest animals, but with ordinary foresight in the planning and construction of the communication between the interior channel and the gully no special anti-draught measures are usually necessary If possible the interior channel should discharge through an end wall, but where this is not possible the surface channel may be sloped to the middle of the shed and the outlet carried through a wall opening or doorway. In the latter case, and with cross-gutters in any passage-way, the channel, if part of a passage-way, should be covered by a movable steel plate

Until comparatively recently it was the custom to use underground drains for the interior of animal houses, and especially in stables This system has been superseded by the surface method. With the old system it was the custom in the case of a stable to have a pipe running the length of the building behind the stalls, and for the urine of each stall to trickle through a trap into the pipe. Similarly in loose-boxes a gully trap was placed in the centre of the floor, which was graded from all the sides of the box to the gully The main stable drain was trapped outside the stable before joining up with the sewer pipe, or passing to the manure pit or liquid manure tank, as the case might be There are serious object ons to underground drains for animal buildings Whatever kind of trap is used in a stable a certain amount of solid always finds its way into the drain ; the amount of fluid that enters the traps and pipes is very small and consists almost exclusively of urine It is not difficult to understand that both traps and pipes become receptacles rather than carriers of urine and manure which decompose with the liberation of objectionable gases into the stable The smell that arises from these traps when they are cleaned out, which not infrequently is only done when they become blocked, is nauseating Stables are not customarily flushed out, but when they are underground drains get choked. When peat moss is used for bedding it is necessary to close up all such drains and traps to prevent the urine-sodden moss from getting into the pipes Wherever underground drains have been installed, and they are still to be found in many old stables to-day, foul smells and a great deal of trouble from blockage are inevitable

With surface drainage, on the other hand, there is simply a shallow open channel running down the length of the stable, to pass, still as an open channel, through the wall to empty into a trap outside the building. The advantages of this system over the old one are at once apparent There are no traps to get blocked, and there is no formation of sewer gas to pollute the air, and there is a greater economy in construction. In order to keep the floor clean, all that is required after the horses have gone out in the morning is to make up the beds and flush the stalls and urine channel with a few buckets of water and brush down.

Gully Traps and Drains.

Any system of drainage must comply with the requirements of the Local Sanitary Authority All gullies must be placed outside a dairy cowshed A type of gully trap sometimes recommended for stables and other animal buildings, except cowsheds,

is illustrated in Figs. 18 and 19. A better type is that illustrated in Fig. 22; this is a self-cleansing trap, which only requires flushing with water to keep it in a hygienic condition. *Gully traps suitable for dairy cowsheds are dealt with in connection with installations for the conservation of liquid manure.* (See below.)

The following quotation from a Memorandum on Farm Buildings prepared by the National Veterinary Medical Association of Great Britain, dated January, 1943, very appropriately summarizes the veterinary standpoint regarding the ultimate disposal of liquid excreta from farm buildings :—

"On the grounds of hygiene, disease prevention and the conservation of manurial value, the use of soak-away pits, pervious septic tanks, or the discharge of liquid manure into open field
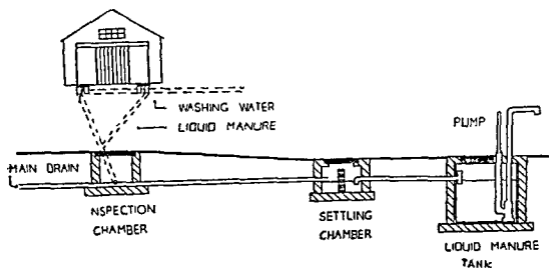
Fɪɢ. 28.—A Cowhouse Drainage System providing for conservation of liquid manure.

ditches, ponds or streams cannot be recommended. The spread of (animal) sewage-borne diseases is too serious to be neglected in this way and the Association hopes to see all farm steadings provided with facilities for the control, storage, and proper utilisation of liquid manure."

Liquid Manure Tank. A suitable illustration for the conservation of liquid manure is shown in Fig. 29, which shows the detailed drainage system from a cowhouse. Because of the large quantities of water used for cleaning the standings of a cowhouse and for the washing of the cows prior to milking, it is essential with liquid manure installations to have some means of diverting this waste water from the main drainage-flow to the storage tanks. This is achieved by fitting a double gully at the exit of the surface channel from the cowhouse. Such a device allows of the disposal of the washing water to any
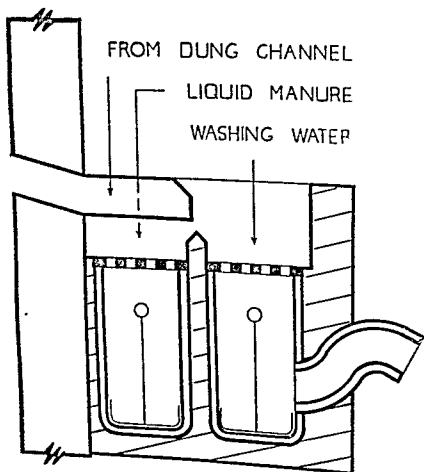
FROM DUNG CHANNEL

LIQUID MANURE

WASHING WATER

Fig 29.—A simple device for the separation of liquid manure and washing water.

convenient and suitable outfall; the liquid manure is conveyed *via* an inspection chamber and a settling chamber to the storage tank. The most satisfactory type is shown in Fig. 28. Washing water flowing rapidly falls into the right-hand trap and is conveyed to the outfall; liquid manure drips into the left-hand trap which is connected with the storage tank.

The liquids from all the animal buildings on the site should be brought to converage at one point if possible. At the point of convergence the pipes meet in an inspection chamber fitted with half pipes. From this chamber one pipe carried the liquids from all sources to a settling chamber. The settling chamber is constructed of cement concrete throughout, or with cement concrete floor and walls of brick faced with cement. It is divided into two parts by a movable vertical plate which fits with grooves at the sides and bottom. This plate must be perforated so as to let the liquids pass through to the distal side of the tank while the solids are retained on the inlet side. The outlet pipe leading to the liquid manure storage tank is bent down so as to dip into the liquid, thus forming a seal to prevent the backflow of gases from the storage tank, thereby conserving the ammonia in the liquid manure. The storage tank must be placed at a point suitable for the collection of the liquid and its distribution to all parts of the farm; close proximity to a roadway is therefore desirable. Its location must be such that the tank does not create a nuisance.

The capacity of the storage tank will depend on the size of the herd, the time the cows spend indoors and the period of storage. If the cows are housed day and night and the tank is to be emptied once a week, the Committee on Farm Buildings (see *Post-War Buildings* Studies, No. 17, para. 204) recommends that about 3½ cubic feet of tank capacity for each cow will probably be adequate. This, however, will involve frequent emptying of the tank, and situations are bound to arise when it cannot be done weekly, *e.g.* owing to bad weather or season of the year. In such a case, when the tank is full the liquid manure may be distributed over the solid manure and straw in the storage pit, provided the pump from the liquid tank is suitably sited for this purpose and is provided with a swivel top. Alternatively, the tank should be of such a capacity to obviate the necessity for over-frequent emptying. The Ministry of Agriculture* suggest that as a general rule and allowance of 12 to 15 cub. ft. of tank capacity for each cow will meet practical requirements.

The tank must be made of impervious material throughout, and

*See Advisory Leaflet 232, "Liquid Manure Tanks."

the bottom should be constructed of reinforced concrete   The sides may also be built of reinforced concrete or, alternatively, be brick-built and faced inside with a good coating of cement   Absolute gas tightness in a liquid manure tank is essential in order to conserve the ammonia   The top must be fitted with a manhole, the cover of which should be of iron with a tongue to fit into a groove in the frame, which is filled with grease so as to form a gas-tight joint. The pump for extracting the liquid should be as simple as possible, coupled with efficiency, and should be so fitted that no escape of gas is possible.

ANIMAL EXCRETA AS A FACTOR IN THE SPREAD OF DISEASE

It may be stated as a general principle that manure is potentially dangerous to the health of livestock, and in its disposal, therefore, all measures which will serve to keep manure, with its content of bacteria, protozoa, worm eggs and larvae, from contaminating the food or water of livestock should be adopted   Whilst there are limitations to the procedures which can be carried out with this object in view, particularly with animals at pasture, a great deal more than is frequently done could be undertaken for the more effective treatment of manure as it accumulates in or near animal habitations   Obviously manure should be removed from stables, byres, sties and similar places frequently and thoroughly and, once removed, it should be disposed of in a way which is both satisfactory and practical

The scientific control of organisms that may cause disease depends on a knowledge of their life history and bionomics, and consists essentially in making their development as difficult as possible   In the case of organisms which are excreted in the faeces or use the faeces as breeding sites, it is possible to attack them by suitable treatment of the manure   One method is to disregard the organism content of the manure, and to secure its dispersal in such a manner as to effectively keep it from being a source of harm to susceptible animals; the other method is to treat it in such a manner that the organisms in it are destroyed.

Some Important Organisms occurring in Excreta. Numerous organisms inimical to the health of livestock occur in animal excreta. Some are excreted in the droppings or urine of diseased or carrier animals, whilst others use the faeces as suitable breeding material. Amongst examples of the former may be mentioned the virus of swine

fever and, although this organism, which is readily destroyed by drying, probably does not remain alive outside the body during warm weather for more than a few days, it may be carried by animals, possibly by birds, and on the footwear and clothing of persons coming in contact with infected manure, particularly when the latter is sodden with urine.

Amongst pathogenic bacteria which are excreted in faeces, mention must be made of Johne's bacillus. Lovell *et al.** have recorded that naturally infected bovine faeces, even when left exposed to atmospheric conditions involving alternate drying and freezing, may contain viable Johne's bacilli as long as 246 days after exposure. These authors consider it a sound policy to encourage such measures as the breaking up of droppings on infected pasture land and the disposal of dung from standings to cultivated, land, besides the draining and fencing of ponds.

The anthrax bacillus is another micro-organism which occurs in the excreta and discharges of diseased animals. In addition to carrion-eating animals and birds of prey, insects, especially blood-sucking flies, must be considered as potential disseminators of infection, particularly in hot climates where flies are abundant. Experimentally, at least, the House-fly and Stable-fly which frequent manure have been shown to be capable of conveying the spores of anthrax.

Amongst other bacteria which occur in excreta and may cause disease are organisms belonging to the *Clostridium* and *Salmonella* groups.

Of the Protozoa which are excreted in faeces, coccidia are important in the production of disease amongst both animals and birds. Owing to the resistant nature of the oöcysts, especially when sporulated, they not only may remain alive for periods of many months but are difficult to destroy by most chemical disinfectants which may be added to the manure without at the same time destroying the fertilizing value of the dung.

Numerous helminths occur in the droppings of livestock, mostly in the egg stage, but a few as larvae, and may be transmitted from the diseased to the healthy animal by contaminated food or water which contains the infective stages of the worms. The redworms, or strongyles, or horses, the lungworm of cattle (*Dictyocaulus viviparus*), *Habronema* species of horses, which use House-flies and Stable-flies as vectors, and some of the avian tapeworms, which require certain arthropods as intermediate hosts, are examples of helminths which may be spread from manure.

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*Lovell, R., Levi, M., and Francis, J. (1944). Studies on the Survival of Johne's Bacilli. *J. Comp. path.* 54, 120-129.

Organisms which use faeces as breeding material are principally insects, particularly flies. They are mainly important in playing the rôle of disseminators of disease producing organisms.

Pathogenic organisms occurring in faeces of infected livestock may be spread to healthy animals by several other methods in addition to their dispersal by insects. They may be carried on the clothing and footwear of persons whose business it is to remove faecal matter from byres and stables, or they may contaminate food stuffs as, for example, when dung is distributed over land where green crops are being raised for animal food. Limited spread may occur over the ground adjacent to a manure heap when organisms are washed or drain out of the pile after heavy rain or when the faeces are mixed with a high proportion of urine. Birds may, to some extent, be responsible for disseminating pathogenic organisms since some species frequent manure heaps in search of seeds and insects and, in doing so, pick up infective material on their feet and legs and convey it elsewhere,

Manure as a Breeding Material for Flies. Of the flies which select manure as a breeding material, the most important is the cosmopolitan House fly (*Musca domestica* L). Other flies which frequent human and animals habitations and use dung as a breeding material are *Musca sorbens* Wd (or *humulis* Wd.), a common fly in the tropics and sub-tropics, *Fannia canicularis* L or the Lesser House fly, *Muscina stabulans* Fln and the cosmopolitan *Stomoxys calcitrans* L, commonly known as the Stable-fly or Biting House-fly. Horse, pig, and, to a lesser extent, cattle dung appears to be the most favoured materials in which these species of flies breed. The breeding places are, however, determined by the needs of the fly during its larval stages and the female oviposits only in material which can provide food in a readily assimilable form, sufficient moisture and, usually, warmth and shelter for the developing maggots.

In the case of the House-fly, accumulations of fermenting horse manure normally form the principal breeding places in temperate climates. This insect can, however, also breed in pig dung, exposed human faeces, decaying and fermenting organic matter of various kinds to be found in ash pits and the like, and in poultry droppings. It does not breed in cow dung scattered in fields, but this material when mixed with straw may form a breeding place. Although horse manure is the chief breeding site, this material is attractive to ovi-positing House flies only so long as it is fresh and not much older than twenty four hours. The corollary of this is that a manure heap to which no fresh additions are made ceases to be a breeding site after the first crop of flies have hatched out from it.

Musca sorbens breeds in sites very similar to those frequented by
the House-fly, and it will also breed in cow dung lying in the field or
stacked, and in isolated deposits of human faeces. Another allied
species, *Musca autumnalis* De G., breeds in cattle droppings scattered
in the fields, as also does *Muscina stabulans*, often called the Non-
biting Stable-fly, which commonly occurs in houses, stables and other
farm outbuildings. The maggots of these two flies develop in situations
where, unlike House-fly larvae, they cannot be economically attacked.
The Lesser House-fly, *Fannia canicularis*, and its near relative, *F.
scalaris*, the Latrine-fly, sometimes frequents buildings. The larvae
may be found in the drier parts of manure heaps and other places
where there is decaying organic matter, in the soil of hen-runs or in
the urine impregnated sawdust or other litter in rabbit hutches or
cages of animals.

Although there are several species in the genus *Stomoxys*, the
Biting House-fly, *S. calcitrans*, is the commonest and the most import-
ant. This fly deposits its eggs in moist, decaying vegetable matter
such as piles of waste litter and food-stuffs that may collect in a farm-
yard, get wet and decay or are wetted with urine or have a certain
amount of manure added to them. Another common breeding ground
is stale farmyard manure mixed with straw, as in a manure heap.

The larvae of species of the biting-flies *Haematobia* and *Lyperosia*
are found in cattle dung lying on pastures.

Principal Points in the Life Cycle of the House-Fly. The veterin-
arian is chiefly concerned with control measures against the breeding
of flies which frequent stables, stock-yards, abattoirs, drains, garbage
dumps, and places such as military camps where the occurrence of flies
in great numbers may result in epidemics of typhoid fever and other
diseases. This fly nuisance can be overcome, and in fact entirely pre-
vented, by the intelligent application of our knowledge about the life
histories of the insects involved, particularly as regards the following
points which refer especially to the House-fly, the most important pest
concerned. The whole life-cycle of *Musca domestica* can be completed
under very favourable circumstances in 8 to 9 days although a further
period, which may vary from 14 to 18 days in Britain but may be very
much shorter in other parts of the world, must elapse before the newly
emerged flies are capable of laying eggs. The rate of development
varies greatly depending upon the temperature of the air and of the
food material, and upon the nature of the food and other factors. In
very warm weather development in Great Britain may, therefore, be
completed and the flies ovipositing in about three weeks after the eggs,
from which the insects originated, were deposited. Oviposition takes

place in faeces within 24 hours and often within 8 hours of their being deposited, later than this faeces appear to have very little attraction for flies   The eggs are deposited in small masses of 120 to 150 in crevices below the surface of the manure   A female House-fly may deposit five or six such batches during her lifetime and may produce in all from 600 to 900 or more eggs   The maggots avoid light and burrow into and feed upon their food material   They do not, however, occur throughout a manure heap but are usually restricted to the superficial layer, at the most from 4 to 5 inches deep, because the heat produced by fermentation makes it impossible for them to live at deeper levels   When ready to pupate the fully fed maggot leaves the manure heap to find a drier and cooler place outside the base of the heap in which to undergo its metamorphosis   This may be in the immediate proximity of the heap under the cover of overhanging straw or at some distance away, usually up to 3 to 4 feet, but sometimes as far as 50 yards, from the heap   Pupation occurs beneath the soil surface at depths of from an inch up to two feet, depending upon the nature of the soil

Range of Flight of House-Fly.   A point of considerable practical importance in connection with the search for breeding sites and, in certain instances with the dissemination of disease producing organisms by House-flies is the distance to which these insects are capable of flying, either unaided or with the help of winds   This is a factor in the spread of disease which is frequently not realised or else overlooked There are records of experiments and of observations to show that House-flies, which have a natural tendency to disperse from their places of origin, can fly long distances   In one instance, the maximum spread in open country from the point of release of marked specimens of *M domestica* and allied species was 13 miles   In towns, whilst flies do not travel as far as in open country, they may nevertheless spread for distances of from a quarter of a mile up to a mile or more There is enough evidence to show that the House-fly is "essentially a migratory insect" and that "it is a false idea to assume that when flies breed out near 'food and shelter' they necessarily do not migrate far"

Fly-Borne Diseases.   The House-fly, as well as some of its allies, is not merely a nuisance in disturbing the rest of man and animals, is especially in warm climates   but can become in certain circumstances, a carrier of disease and, therefore a serious danger to human and nimal health   The diseases which this insect carries, or is capable of carrying, are not restricted to dysentery, cholera, typhoid fever and some infections of man by parasitic helminths, the fly is also an impor-

tant factor in the spread of infantile or summer diarrhoea which results from the consumption of fly-contaminated milk by babies. Reference has already been made to the carriage of anthrax spores by the House-fly and Stable-fly and to the fact that both flies may act as vectors of *Habronema spp.* parasitic in horses. Houseflies are also associated with the life-cycle, and consequently the transmission, of certain other species of parasitic worms infesting domestic animals.

It is generally considered that the organism (*Corynebacterium pyogenes*) responsible for Summer Mastitis of dry cows and heifers is transmitted by flies.

Methods of Manure Disposal to Prevent Fly Breeding. With regard to the disposal of manure, the important question is : How best can it be handled, whether in small or large quantities, after it has been passed by the animals so as to prevent it from becoming a source of infection for other animals or from providing a breeding ground for flies?

(a) *Incineration and Burial.*—Manure, particularly horse manure, is a valuable land fertilizer and whenever possible should not be burnt or deeply buried. When, however, it is neither practicable nor desirable to conserve it as a fertilizer, incineration is the best method of· disposing of it. The manure may be simply burnt on a hard piece of ground making certain that there is a good layer of ash on the surface after the dump has burnt out, which will deter flies from ovipositing in any portions of the dung not completely destroyed. Several different types of incinerator for burning manure have been designed. Whatever type is employed it must be efficient for its purpose and there must be no accumulation of manure either in or alongside the incinerator, otherwise fly breeding will readily occur in the unburnt faeces.

The deep trenching of horse manure, unless performed with care and thoroughness, may prove to be a fertile source of fly breeding. Simple burial of the material in sand or ordinary soil will not prevent the development of House-flies, which have considerable powers of burrowing upwards both as mature maggots and as newly hatched flies to gain the soil surface. Furthermore, the simple burial or ploughing under of manure cannot be guaranteed to dispose of nematode eggs and larvae. The larvae of equine strongyles can migrate upwards for varying distances according to the nature of the soil and, moreover, can live for many months under favourable conditions of temperature and moisture in the soil. Similarly, cattle and sheep roundworm larvae, such as *Ostertagia, Haemonchus,* and *Nematodirus* can all regain the soil surface after being ploughed under; in fact, ploughing-in

may help development of the nematodes by breaking up the soil and faeces

(b) *Use of Chemical Agents*—The application of chemicals and oily fluids to manure in order to deter flies from ovipositing, and for killing fly larvae, worm eggs and larvae, and other pathogenic organisms has been suggested The general use of these substances for the purpose of combatting the fly nuisance is, however, of doubtful value because (i) most chemicals, when applied in large quantities to manure, retard fermentation and so prolong the period of fly infestation ; (ii) most chemicals, if they are to be effective, require to be used in large quantities, so that this form of treatment is expensive and deleterious to the manure, rendering it totally unfit for agricultural uses ; (iii) before they can be effective as larvicides, most chemicals require to be intimately mixed with the manure—a costly procedure requiring considerable labour and careful supervision, and (iv) some of the substances which have been suggested may have poisonous effects should the treated manure be allowed to come in contact with plants or animals

There are, however, certain substances, relatively free from the objections enumerated above, which have been shown to be effective in preventing the House-fly from breeding in manure heaps One of these is powdered hellebore, which has no ill-effects upon the manure or on crops to which the manure is later applied To prepare for use, one half-pound of the powder should be mixed in 10 gallons of water and left to stand for 24 hours This amount, applied with a spray or watering-can to the manure as soon as it is removed from the stable, is sufficient to treat 10 cubic feet (or 8 bushels) of manure, during application the manure must be turned over so as to bring the liquid into contact with every part of the mass Another satisfactory agent is powdered borax, this may be applied dry at the rate of 1 lb of borax to each 16 cubic feet of manure, which must then be watered, care being taken not to add more water than the manure will soak up A solution of 1 lb borax in 6 gallons of water may also be used A degree of caution is necessary in adding borax to manure, which is later to be used for agricultural purposes, because in large quantities this chemical may have bad effects upon crops, some of which are more sensitive than others in this respect A third chemical that has been recommended is sodium fluosilicate applied as a solution of 1 lb in 15 gallons of water until the manure is thoroughly soaked

Benzene hexachloride and DDT, now used extensively as insecticides, can be sprayed on manure heaps and other fly breeding places Not only are the larvae and young, emerging flies killed but also those adult flies which are attracted to the manure as a place in which to lay

their eggs. Suitably formulated, water-base sprays can be applied to the upper surface and any open sides of manure heaps so that emerging maggots and flies do not escape contact with the chemicals. Greater control is possible if, in addition to the manure heaps, the livestock and the interior of farm buildings are also sprayed. Under normal conditions an even deposit of approximately 200 mgm. DDT per sq. ft. of manure heap surface will give adequate control during the fly season if spraying is carried out at 2-6 weekly intervals. At this rate of deposition, the chemical will not adversely affect the fertilising value of the manure. Fresh manure added to an existing heap, or freshly exposed surfaces where it has been removed, require, of course, to be sprayed.

The effect of the different chemicals on nematode eggs and larvae depends upon the nature and concentration of the chemical added to the manure. While it may be possible, and obviously advantageous, to use a chemical which is lethal to both nematode and fly larvae, it does not necessarily follow that a substance lethal to fly larvae will also kill roundworm larvae. Thus, whilst hellebore will kill fly maggots it is not lethal to sclerostome larvae in faeces. Similarly, for nematode control borax would have to be used in amounts greater than are practicable if the faeces are later to be used as a fertilizer, owing to the toxity of an excessive concentration of borax for plants.

It has been shown that urine, particularly horse urine, has a lethal effect on strongly larvae, and also that ammonia, even in comparatively high dilution, kills with considerable certainty. Although the chemical composition and lethal effect of urine varies with species and according to the food and condition of the animal excreting it, as a rule the addition of 30-40 per cent. by weight of urine to fresh faeces will kill the free-living stages of equine strongyles.

Many artificial fertilizers, when mixed with faecal material, have lethal properties for eggs and larvae, and if care be taken to avoid loss of nitrogen a part, or even the whole, of their cost may be recovered by way of the added fertilizing value of the manurial mixture. Urea appears to be the most potent, requiring only 0.75 per cent. by weight of this substance to fresh faeces to sterilize the latter against strongyles. Closely approximating in potency are calurea used at the rate of 1.25 per cent., and cyanimid used at the rate of 2 per cent. as a powder or 2.5 per cent. if in a granular form. Another fertilizer with lethal action is high grade kainit, used at a rate of 5 lb. to each 100 lb. manure. Several other artificial fertilizers are of larvicidal value, and are generally recommended to be used for this purpose at the rate of about 6 per cent. or slightly more, compared with the weight of fresh faeces. It should be noted that the addition of some alkali fertilizers

to animal manure causes a loss of ammonia, and in the case of urea and calurea much of the ammonia escapes as a gas

The practicability of using chemical substances for rendering animal manure innocuous largely depends upon their cost, and with many of the substances the amounts mentioned above would be too great for general adoption where large quantities of manure have to be treated However, since the heat of fermentation, lack of oxygen, and other factors in the middle of a well constructed stack are lethal to larvae it should be necessary to treat only the freshly passed faeces on the top and sides of the pile The chemical must be well mixed in at once, and the stack firmly packed, the manure must remain undisturbed for some time, so as to allow contact of the fresh faeces and the chemical for sufficiently long for the latter to exert its maximum larvicidal effect In this connection, the use of a well-built manure pit is desirable, this, ideally, should be divided into two parts—one to contain manure under treatment, the other meanwhile being filled When both compartments are full, that already treated is emptied in order to take fresh manure while the manure in the other is now being subjected to treatment

(c) *Manipulation of Manure* —The methods of manure disposal so far dealt with, namely incineration and burial—neither of which are desirable in any agricultural community—and the addition of chemical substances which will kill, or prevent the development of, flies and worms can be regarded as "artificial' procedures In contrast to these there is a "biological' method which involves manipulation of the accumulated manure heap itself in such a way as to kill the preliminary stages of both flies and worms without the addition of any special larvicidal substances This method is relatively less costly and is preferable also on other grounds to those already detailed There are three main procedures by which eggs and larvae in animal manure may be destroyed through biological effects, these procedures may, for convenience, be called (i) "spreading' or "drying," (ii) "turning over the surface," and (iii) "close packing"

Spreading or Drying. This is a method which is only occasionally possible in temperate zones, but which is suitable in hot, dry climates, and especially in countries where dried manure is used as fuel or North Africa, when the preservation of manurial value is secondary to military considerations The method consists in spreading within 24 hours of its being voided each day's output of manure in a thin layer, so that it may be subjected to rapid desiccation by sun and wind.

Rapid and regular daily drying is essential as only the eggs and pre-infective stages of strongyles are easily destroyed by desiccation. Moreover, dry or drying manure does not attract ovipositing flies, and any maggots already present therein cease development and die. The method should be worked on the "three day system," using three areas of ground each just large enough to take one day's output of manure when it is spread out thinly. Each area is covered in turn, and before re-using an area again the dried dung may, where necessary, be swept or raked to one side for burning. The final disposal of the manure by burning is the logical extension of the drying process.

Turning over the Surface. The basic principle of both this and the close-packing method is the utilization of the natural heat which is generated in fermenting manure for the purpose of destroying the eggs, larvae, and pupae of flies and the eggs and larvae of round-worms normally present in the dung of farm livestock. A well-packed stack of horse manure becomes very hot after an interval of from one to three days. The temperatures attained vary at different depths ; at one inch below the surface the heat registered may lie between 87° F. and 97° F. ; at four inches below the surface it will range between 145° F. and 156° F. ; at six inches depth it will commonly be about 158° F. whilst at a depth of ten inches it will be about 160° F.

In general a temperature level that will destroy the strongyles of horses will also destroy almost any of the related parasites of other livestock, as equine redworms are amongst the most hardy of the nematodes so far as resistance and viability of the larvae are concerned. Various reports indicate that the infective larvae of horse strongyles can survive exposure to a temperature of about 125° F. for about 20 minutes only and that they are killed almost instantaneously at about 130° F. The eggs are apparently somewhat more resistant, but it would appear that they are quickly killed at temperatures between 140° F. and 158° F. The first stage larvae of *Musca* are readily killed at temperatures between 104° F. and 120° F. while in the second, and especially the third, stages the larvae are killed by exposure to 130° F. As a rule sufficient heat will be generated by fermentation in a tightly-packed stack of horse manure to kill during the first three days all fly larvae and worm eggs and larvae buried at a depth of six inches below the surface. Atmospheric warmth combined with moisture accelerates the fermentation of organic manure, whereas dry heat, or cold, retard it. Finally, it must be noted that, whilst the lethal effect of the heat generated in fermenting manure is undoubtedly great, the killing of eggs and larvae is not secured by this means alone; gases liberated
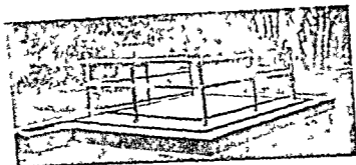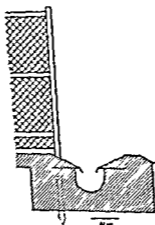
—V.H. 9

Fig 30—Baber's manure platform

Fig 31.—To illustrate construction of gutter for Baber's manure platform
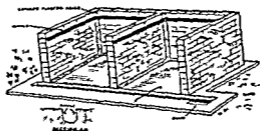

Fig 32—Allnutt's manure pit

during the decomposition of dung also exert considerable toxic action on these stages.

It would appear, then, that a simple method of dealing with fresh manure so as to free it from these free living forms of parasitic life is to bury it in a mass which is already undergoing fermentation ; *i.e.*, fresh manure, instead of being thrown on to the surface of the stack, should be buried at a depth which ensures a surrounding temperature high enough to prevent eggs hatching and to kill any larvae that may be present. The outside layer of the stack must be buried periodically in a similar fashion. The procedure outlined here is the essence of the "turning over the surface" method which, it must be recognised, entails a degree of labour and of intelligent and conscientious application that is seldom possible or available under most conditions of animal management. For these reasons, other procedures have been devised which are simpler to work, but which on the other hand involve some initial financial outlay. The majority of these procedures are based upon the "close packing" principle, to be described below.

Close Packing. The simplest form of this method consists in making a compact block of manure of any desired horizontal dimensions but, which for ease in its subsequent treatment, should not exceed about five feet in height. The site selected must have a hard level surface and be somewhat greater in extent than the final base area of the intended dump. Each day's output of manure as it is added to the block must be firmly pressed down with shovels or other means, the sloping sides of the growing pile at the same time being consolidated and smoothed.

Adaptations and modifications of the essentials outlined above which have proved successful in practice are the Patton, Baber, Allnutt and Hutchison trap methods. All have been devised for the purpose of fly control, and are founded on the fact that third stage *Musca* larvae must migrate out of faecal material in order to pupate. Accordingly, by using a receptacle which the larvae are bound to enter during migration, and from which they cannot escape, they can be collected and destroyed with certainty and ease.

Patton's is the simplest form of trap, consisting merely of an impervious floor upon which the manure is placed. Around the edge of the floor, but quite clear of the packed manure, runs a trench or gutter, which has straight and smooth sides and is 4 inches deep × 6 inches wide, into which the third stage larvae fall during their migration. The larvae so trapped should be collected daily for destruction.

Baber's method is an elaboration of Patton's and makes for more efficient working. The structure for retaining the manure should be substantially built and have four compartments, each sufficiently large to hold a week's output of manure. Each compartment is floored with cement concrete, sloping downwards at the edges to a surrounding gutter. (See Figs. 30 and 31.) Retention of the manure is secured by an enclosure of strong iron posts and wire netting erected

ted on the floor The manure must be tightly packed into the various compartments in turn, and must be moistened if it is too dry and be protected against heavy rainfall by a covering of some sort Any maggots not killed by the heat of fermentation and leaving the manure to seek a pupation site are trapped in the gutter, from which their escape through crawling up the walls can be prevented by fitting a metal overhang to the edges of the gutter , this may conveniently be constructed from ordinary sheet galvanised iron, about 6 inches in width, and bent down one and a half inches at its free edge All joints in the overhang must slightly overlap since maggots will find, and escape through, any openings left between the ends of the metal sections The gutters slope to a sump of appropriate size into which the drainage from the manure is collected It is important that the edges of this sump be provided with a metal overhang similar to that of the gutter, as the majority of the larvae migrate towards the sump and will readily escape therefrom if no provision is made for their detention If the gutter be not kept free at all times from litter and other solid material, which readily find their way into it, it is obvious that the whole trapping system will be rendered useless If desired the gutter may be filled with any suitable disinfectant or fly poison The method of using Baber's trap is to deposit one week's output of manure in each of four compartments in rotation , this allows the manure being left in any one of the compartments for three weeks, after which interval it is no longer attractive to flies and may be considered to be cleared of fly larvae and also, except for the outer edges of the stack, of strongly larvae If, however, complete destruction of the latter is desired the edges of the stack should be removed and buried in fermenting manure or alternatively this material may conveniently form the nucleus of the succeeding fresh stack One great disadvantage of the Baber trap is that the wire fencing makes close packing of the manure difficult to achieve, increases the area of exposed surface, and hinders the effective treatment of that surface by means of the ' turning over ' procedure

Allnutt's modification is designed to overcome the difficulty of turning the manure He advocates a two-stalled receptacle, walled in on three sides and set on a cement concrete or other strong, impervious platform and having a gutter running across the open front , a median partition wall of the same height as the outer wall divides the receptacle into two equal compartments (See Fig 32.) The surrounding walls and the partition are provided on their inner surface a few inches from the top, with a baffle or ledge projecting inwards in order to prevent migrating larvae which have crawled up the walls from escaping over the edge It is essential for the success of the system that at no time must the manure stored in the compartment reach the height of this ledge The gutter is constructed in a manner similar to that in the Baber trap It extends at both ends slightly beyond the retaining walls and is closed at one end , at the other end it drains into a sump, soak away, or cess-drain, at the entrance of which is a two-inch ledge to maintain a continuous level of fluid in the gutter The gutter can thus be kept always half filled with a solution of cresol to kill migrating larvae and to prevent mosquitoes from ovipositing, which would occur if water alone was used A vertically sliding shutter fitted to the front of each compartment hinders debris falling into the gutter If the walls of the manure pit are likely to be exposed to much rain and thus kept moist—a condition which will aid the larvae climbing the projecting ledge—the gutter should be extended all round the walls so that it will trap any of the maggots which will have surmounted them and would otherwise escape

The idea underlying the provision of two compartments in the Allnutt pit is that while one is being filled and tightly packed, fermentation and decompo-

·sition ·can ·proceed in the other which is already full. The system allows the front
·and top layers of manure to be periodically removed and deposited in the centre
·of the stack with the least difficulty.

Hutchison's method of storing horse manure is to place it on a platform, per-
forated by many fine slits, which stands over a shallow concrete basin sloping
·slightly to one corner where there is an outlet pipe and containing water to a depth
·of half-an-inch in the shallowest part.   In contrast to the other methods described,
it is not necessary to pack the manure tightly on the platform.   The principle under-
·lying this method of dealing with horse manure is to encourage ovipositing flies
to deposit their eggs in it during the 10 or 12 days when it is attractive to the flies,
and then to drawn the maggots as they leave the manure through the slits of the
·platform to pupate.   The water should be drawn off at intervals and the dead and
dying maggots destroyed.   Important difficulties in the system are that the manure
is apt to fall over the sides of the platform and also to work through the slits ; it
·can of course be replaced and, to allow of this, the platform should never be less
than one foot above the basin, but its re-placement may entail excessive labour.
Another drawback is that the manure being over-exposed to the air, tends to become
too dry so that not only is decomposition retarded, but the increased friability
·of the debris makes it difficult to handle as well as allowing it to fall into the basin
more readily.   Further, in dry, hot weather, the water may evaporate rapidly
and so allow the maggots to escape from the empty basin; to ensure against this
possibility, water should be added to the basin when each day's manure is dumped.
If mosquitoes are present it will be necessary to cover the surface of the water in
the basin with oil, a procedure which does not in any way hinder destruction of
·the maggots.   Another not unimportant limitation is that only a proportion of
the strongyle eggs and larvae contained in the manure is destroyed.

In any method of manure disposal where both horse and cattle dung are being
·heaped together, the horse dung should be put on first and the cow dung, which
·is less attractive to flies, applied over it.

SECTION III

AIR, VENTILATION AND LIGHT

AIR AND VENTILATION

It is necessary that the hygienist should have a clear conception of (i) the impurities that may be present in the atmospheric air; (ii) how they accumulate; (iii) to what degree they can be tolerated by man and domesticated animals; and (iv) how polluted air may be purified. When animal life is crowded in a restricted area, as in buildings, the composition and character of the air becomes changed from the normal state to one which, if not necessarily fatal to life, may at least appreciably reduce vitality and productivity. The more confined the space in proportion to the animal life contained within it, the greater is the degree of pollution and the more rapidly does it take place. The problem of ventilation is to secure the continual removal of polluted or vitiated air from occupied buildings and the maintenance of atmospheric conditions which are conducive to comfort and good health.

The Composition of Atmospheric Air. Pure air is a mixture of various gases including a quantity of water vapour; it has the following approximate composition by volume :—

Oxygen	...	...	...	... 20.94 per cent.
Carbon Dioxide	...	...	...	0.028 to 0.04 per cent.
Nitrogen	...	...	...	... 78.04 per cent.
Argon	...	...	...	... 0.94 per cent.
Helium, krypton, neon, etc.		...		Traces.

There are also traces of ammonia, ozone, nitric acid, free hydrogen and methane. On an average air contains about 1.4 per cent. of moisture, which exists as a gas and not in the form of droplets.

Atmospheric Humidity. The term humidity refers to the amount of aqueous vapour present in the atmosphere. The existence of vapour pressure can be shown by introducing a little water into the Torricellian vacuum of a barometer tube. The aqueous vapour which is formed drives the mercury down by an amount which measures the aqueous vapour pressure. If sufficient liquid is present the vapour

pressure reaches a maximum, called the *saturation pressure*, for a given temperature and increases with the temperature   There is always a certain amount of aqueous vapour present in the atmosphere, and it becomes of importance to measure the amount present at any given time

As the air is rarely saturated with water, some means of indicating the amount of water present in the air is necessary   This is done by stating either the absolute or the relative humidity   The *Absolute Humidity* is the actual weight of water present in a stated volume of air   By *Relative Humidity* is meant the ratio of the actual mass of water vapour present in a given volume of the air at any temperature to that mass which would be present if that volume of air were saturated at that temperature   The *Dew Point* is that temperature at which the water vapour then present in the atmosphere would be sufficient to saturate it

Since the vapour pressure approximately follows Boyle's Law we see that —

$$\text{Relative Humidity} = \frac{\text{Saturation vapour pressure at dew point}}{\text{Saturation vapour pressure at air temperature}}$$

and it is usually expressed as a percentage

The measurement of the *Absolute Humidity* is obtained by passing a known volume or weight of air over a powerful drying agent such as phosphorous pentoxide or H_2SO_4 so that virtually all the water is removed from the air   The chemical is weighed both before and after the test , the difference in weights gives the amount of water in the known quantity of air

Relative humidity can be estimated in two ways, one of which is from direct measurement of the dew point and the other from the observed temperature of evaporation, i e , the difference between the temperatures indicated by wet and dry bulb thermometers   The apparatus used for determining the dew point consists of a glass tube about 4 ins long at the bottom of which is soldered a very thin silver thimble   This thimble is filled with ether, and the air is bubbled through it, thus cooling the thimble by evaporation of the ether   At a certain temperature a thin film of dew will form over the thimble , this temperature is the dew point   From the temperature of the dew point and that of the air, the relative or absolute humidity can be obtained from reference tables   This method depends for its results on the

quickness with which the dew is first observed; this is not easy and requires some practice.

The method involving dew-point measurement has been found to be too tedious for routine estimation of relative humidity; calculation from the known wet and dry bulb temperature is more suitable and gives sufficiently accurate results. A description of this method will be found at the end of this Section. (See p. 151.)

Pollution of Atmospheric Air. Pure air is never found in the immediate vicinity of animals or people, because by them the proportions of its constituents are altered and foreign matters, some of which may be harmful, are added to it. The normal physiological processes cause a reduction in the amount of oxygen, an increase in the carbon dioxide and methane, and an alteration in the physical character of the air by increasing its moisture and temperature. The combustion of coal and other fuel, the decomposition of animal and vegetable matter, the combustion of illuminating and heating gases and the various trade and manufacturing processes all take a part in rendering the air less pure. Factories discharge various gases and substances in suspension into the atmosphere, some of which may be deleterious and some harmless. Chemical works add sulphur dioxide, sulphuretted hydrogen and other gases, but the discharge of such gases into the atmosphere is regulated by the Alkali Acts, which require that, in the case of hydrochloric acid gas, not more than one-fifth of a grain per cubic foot of air, smoke or chimney gas may pass out into the atmosphere. Of the acid gases of sulphur and nitrogen, not more than the equivalent of four grains of sulphuric anhydride per cubic foot of air may be discharged into the atmosphere.

Free ammonia resulting from the decomposition of urea is to be found in the air of badly constructed and badly ventilated animal houses; under good hygienic conditions and with good stable management it should not be present in appreciable amount. A considerable amount of organic and particulate matter is also commonly present in the air of animal habitations. This may be in the form of droplets of moisture arising from pulmonary exhalations, or which may be projected into the atmosphere during coughing or sneezing. Suspended impurities originating from cuticular debris, from desiccated faeces, from the dust and pollen of feeding stuffs and bedding materials will also be present. Associated with the liquid droplets or with the dust in the air of animal buildings, there are always to be found moulds and bacteria of diverse kinds, which under certain circumstances may acquire pathological significance for animal health, or which may be of real hygienic importance, as for example, in "clean" milk production.

CHANGES IN THE AIR RESULTING FROM RESPIRATION

Respiration is basically a gaseous exchange between an organism and its environment, which results in chemical and physical alterations in the expired as compared with the inspired air. The chemical changes arise from the absorption of O_2 and the elimination of CO_2 by the blood in the pulmonary capillaries. Expired air thus contains less O_2 and more CO_2 than inspired air. The following percentage composition by volume for the expired air of man may be taken as representing the average results of numerous investigations —O_2 16 4; CO_2 4 24, N_2 and other gases remain substantially the same as in the inspired air. From these figures it may be calculated that at each respiratory act in man 100 volumes of inspired air loses about 4½ volumes of its O_2, and gains 4 volumes of CO_2. The expired air of herbivorous animals, in addition to O_2, CO_2 and N_2, also contains considerable amounts of methane derived from carbohydrate fermentation in the alimentary canal. Moreover, variations in the chemical composition of the expired air in all species are brought about by changes in the kind of foodstuffs being oxidized, and by alterations in the frequency and depth of respiration.

The amount of CO_2 excreted during normal metabolism by an average man at rest is 0 6 cubic feet per hour, this amount is increased with active work and during the eating and digestion of food. Estimates given by various authorities of the CO_2 excretion by horses and cattle differ considerably, which is to be expected, since the weight and surface area of the different breeds and types vary greatly. The rate of CO_2 excretion, and also of heat loss, depend upon the ratio between the surface area of the body and its weight. Thus weight for weight large animals will produce proportionately less CO_2 than small ones.

Armsby & Kriss* give the following average figures for the hourly excretion of CO_2 —

	Cubic Feet
Cows in milk	
Horses	5 8
Swine	3 9
Sheep	1 3

A dog weighing about 50 lbs excretes approximately 0 3 cubic feet of CO_2 per hour. For cows in milk and fattening cattle on full rations, 6 cubic feet per hour may be taken as an average figure. Similarly, for heavy draught horses weighing approximately 16 cwts, the amount of CO_2 may be put at 6 cubic feet per hour.

*Armsby & Kriss (1921)   J Agri Res 21 323

In addition to the chemical changes in expired air mentioned above, certain important physical changes take place. Expired air is warmed to the temperature of the body, and in the lungs it has become practically saturated with water vapour, as can be clearly seen by the condensation cloud which forms in cold weather when the warm, moist exhalations come in contact with the colder atmospheric air. Another effect of warming is that the air of expiration has a greater volume, *i.e.*, is less dense, than the normal atmospheric air. This latter fact forms the basis of all systems of natural ventilation in occupied buildings, in that the warmer, less dense air tends to rise, its place being taken by cooler air entering at a lower level.

The Significance of the Changes in Expired Air. The immediate ill-effects experienced by human beings in poorly ventilated rooms include depression, headache, drowsiness, and a general inability to do efficient physical or mental work. The effects of prolonged confinement in badly ventilated buildings, on the other hand, are not well understood, but there is considerable evidence of the unfavourable influence which habitual exposure to vitiated air may exert on bodily function. Thus it is a common observation with regard to both man and domestic animals that natural resistance to disease, particularly respiratory affections, is lowered by continued living in poorly ventilated surroundings. In the case of animals, too, there is some evidence which suggests that slight but significant increases in the yields of milk or of eggs have rsulted when the cows or fowls respectively were maintained under improved air conditions. An understanding of the significance of the changes in air composition resulting from the confinement of animals in buildings is, therefore, essential to the problem of ventilation.

It was formerly believed that the discomfort and other ill-effects experienced by the occupants of crowded and badly ventilated buildings were attributable to a decrease in the O_2 and an increase in the CO_2 in the expired air. This idea was refuted by Sir Leonard Hill and his collaborators as a result of an extensive series of critical experiments, which provided convincing proof that heat stagnation, due to excessive moisture and lack of air movement, was the real cause of the discomfort. (See Local Govt. Board Rept., New Series, No. 100, 1914 ; and M.R.C. Repts., No. 32, 1919, and No. 52, 1920.)

Oxygen Decrease. The work of Hill showed that man experiences no discomfort even when the percentage of O_2 in the inspired air drops to 15 per cent., a level at which ordinary combustion, *e.g.* that of a match or a candle, will not take place. In greatly overcrowded rooms

the O₂ content is said rarely to fall below 20 per cent. It is not until the O₂ content of the air drops to less than 12 per cent that harmful effects are experienced by man. 'A person not exerting himself will fail to observe any effect until the O₂ has been reduced to 12 or 10 per cent, and consciousness will not be lost until the percentage sinks below 7 per cent.' Clearly, therefore, it seems safe to assume that a diminution in the amount of available O₂ cannot be regarded as an important factor in producing the more immediate bad effects experienced as a result of inefficiently ventilated rooms.

Carbon Dioxide Increase. The air of occupied rooms or buildings always contains an amount of CO_2 greater than that found in the outside air, but under ordinary conditions the amount of CO_2 in an indoor atmosphere never increases to such an extent that breathing the air will give rise to toxic symptoms in men or animals. In overcrowded places like theatres or lecture rooms the CO_2 concentration rarely ever exceeds 0 5 per cent, whilst in ordinary commercial cowsheds it has been found that the average amount of CO_2 usually lies between 0 2 and 0 3 per cent. Experimental evidence from various sources indicates that CO_2 may be present in the respired air to as high a concentration as 2 or 3 per cent without an individual exposed to it being aware of anything unusual. In breweries and in coal mines the CO_2 content of the air may be as high as 2 per cent without causing any noticeable effect on the men working in these places. In submarines men can work in atmospheres containing as much as 3 5 per cent CO_2. At concentrations of 3 per cent or over respiration in man becomes accelerated, at 5 per cent distinct panting becomes evident. At a concentration of 7.8 per cent the horse is said to be able to live, but exhibits severe dyspnoea.*

The formerly held view that CO_2 was distinctly deleterious to health if present in anything but a very small percentage above the normal is now untenable in the face of scientific facts of the kind cited above. Since, however, the increase in the amount of CO_2 in the air of a building resulting from the metabolism of animal life therein, may be said, in some degree, to occur *pari passu* with other changes, such as decrease of O₂ and increases in temperature and humidity and of air-borne organic matter, increase in CO_2 concentration above the normal has been taken as an index of air pollution, and, therefore, indirectly as a means of indicating the efficiency of a ventilating system. The parallel is not, however, a complete one since variations in temperature and humidity in the external atmosphere will influence

*Iuchi, N (1922) *J Amer vet med Ass* 62, 74.

conditions inside the building without any change in the CO_2 concentration and many hygienists now regard it as erroneous and unscientific to rely upon CO_2 determinations of the air as a sole measure of its fitness for respiratory purposes.

Increase of Temperature and Humidity. Where animals are confined in an inadequately ventilated building it is a commonplace observation that both the temperature and moisture content of the atmosphere become markedly raised. The sources of these physical changes in the air of the building are the heat and water losses arising in the animal body. In an environment where both temperature and moisture have become unduly high, the physical condition of the air becomes such that the rate of heat loss from the body is greatly reduced. It should be evident that such an atmosphere is a poor one for the taking up of heat liberated *via* radiation or for the vaporization of water, the two chief means by which the body gets rid of its excess heat. A high environmental temperature depresses rate of heat loss by radiation, high air humidity reduces evaporation, and lack of air movement still further limits evaporation because of the envelope of warm, moist air which tends to form around the bodies of individuals placed in an atmosphere where there is little or no air velocity, *i.e.* when ventilation is inadequate. The net result of exposure to such a set of environmental conditions is heat stagnation in the body, a condition which the work of Hill and others, already referred to, has shown to be the main factor responsible for the discomfort and other symptoms experienced by human beings in poorly ventilated buildings:—"The symptoms arising in the so-called vitiated atmosphere of crowded rooms are dependent on heat stagnation. The essential thing is to keep down the heat saturation of the air in contact with skin. The air entangled in the clothes becomes warmed up to body temperature and saturated with moisture if there is no wind to drive it away." (Hill *et al.*, *op. cit.*)

In animal buildings certain other sources of air vitiation not directly connected with the animals themselves must also be considered; these include decomposing excreta and bedding, water on the floors of cowsheds resulting from washing operations and, in certain circumstances, on the surrounding walls and surfaces, all of which tend to increase the humidity of the internal atmosphere.

TEMPERATURE IN ANIMAL BUILDINGS

Physiological Considerations When the temperature of an environment falls, certain compensatory mechanisms for the reduction of heat loss from the body are brought into play These include vaso-constriction of the cutaneous blood vessels, erection of hair or feathers, and decrease of evaporation from the body surface If the environmental temperature continues to fall, there comes a time when the heat-conserving mechanisms are no longer able in themselves to prevent cooling, and if body temperature is to be maintained at the normal level then metabolic heat production must be increased. The environmental temperature at which suppression of heat loss from the body becomes insufficient in balancing the normal body temperature in the resting and fasting animal, and at which the rate of metabolism must, therefore, be increased if a lowering of temperature is to be averted, is known as the *critical temperature* The critical temperature shows wide variations between different species, and to a lesser extent also between different individuals of the same species A well-developed ability to retain body heat at lowered environmental temperatures indicates a low critical temperature Man artificially lowers his critical temperature, *i e* increases his heat retention, by covering his skin with clothes Hair, fur feathers and thick layers of subcutaneous fat are the natural means which perform a similar function in animals Among farm livestock, cattle and sheep have the lowest critical temperatures and are therefore best able to withstand the effects of cold, whilst the pig, being only very sparsely covered with hair, has a relatively high critical temperature The critical temperature is also influenced by the nutritional plane on which animals may be maintained, heavily fed animals being better able to withstand a low environmental temperature than those existing on a bare maintenance diet

The average critical temperature for the pig varies from 68°F to 73°F For cattle (bullock) with a full coat of hair it has been found to be below 56°F, while for horses it is somewhat higher than this For a bullock with closely clipped hair, the critical temperature is higher than 65°F In a dog before clipping, it was found in one investigation to be between 56°F and 60°F, and after clipping between 74°F and 80°F In the fowl the critical temperature lies between 60°F and 70°F

Temperature of Cowsheds Some forty years ago the Highland and Agricultural Society of Scotland sponsored a series of experiments with a view to determining the optimum environmental temperature

of dairy cowhouses during winter for milk production. Douglas (1911),[*] in summarizing the results of these experiments, has pointed out that the production of milk can be carried on at least as profitably in cowhouses which are ventilated so that the environmental temperature is kept down to 50°F. as in those where it is maintained ten degrees higher by restricting the inflow of air to the buildings. In this author's opinion, a limitation in ventilating efficiency sufficient to raise, and to maintain, the indoor temperature at 60°F. leads to a state of atmospheric impurity inconsistent with the requirements for perfect health. He also believes that any waste of food which may be entailed in the maintenance of body heat of cows kept in cowsheds with lower environmental temperatures is more than balanced by the improved health resulting from the better air conditions.

According to King (1908),[†] the optimum environmental temperature for cattle kept on a high plane of nutrition lies between 45°F. and 50°F., but that with animals on a maintenance diet a higher temperature than this is desirable, viz. one between 55°F. and 65°F., because animals fed at maintenance level are consuming much less food and do not, therefore, receive the benefit of any extra metabolic heat arising from the chemical transformation of this bare sufficiency of food.

For dairy cows having large udders only scantily covered with hair, and through which much blood must flow in the process of milk formation, Armsby and Kriss (1921)[‡] consider that a temperature as high as from 50°F. to 60°F. is probably the best, even with high feeding.

A more recent report by American workers[§] indicates that winter cowshed temperatures as low as 45°F. do not significantly lower milk production; it is confirmed by the workers in question that the optimum house temperature for dairy cattle is about 50°F.

From the data submitted by various authors, and briefly cited above, it is apparent that, although there is a slight lack of agreement in regard to precise optimal temperature requirements, the generally accepted view is that the conservation of environmental warmth in animal habitations should not be obtained by the restriction of ventilation to such a degree that the air becomes vitiated. There also seems to be general agreement that the possible higher feeding costs arising from the housing of livestock in well-ventilated, but cool, buildings, are more than compensated by the improved health and

*Douglas (1911). *Trans. High and Agri. Soc., Scotland,* 23, 170.
† King (1908). *Ventilation for Dwellings, Rural Schools and Stables.* Madison, Wis., U.S.A.
‡ Armsby and Kriss (1921). *Op. cit.*
§ Kelley & Rupel (1937). *U.S. Dept. Agri. Tech. Bull.,* No. 591.

comfort of the animals As far as climatic conditions in Great Britain are concerned, it seems now to be well established that for adequately fed cattle, and also for horses, the need for "warm" buildings in winter is neither necessary nor desirable The optimum environmental temperture for both these species when housed during the winter should be cool rather than warm, but at the same time the temperature should not be so low as to cause a wasteful consumption of food in order to secure the added heat production resulting therefrom for the maintenance of body temperature A similar view is expressed by Speirs'* who states that any saving of food costs by keeping the animals in a warmer environment is equalled, if not exceeded, by a better utilisation of the food when they have plenty of fresh air, but of a lower temperature As a result of observations carried out in Scotland, this author considers that it should be impossible to keep the environmental temperature in any cowhouse at from 60 F to 63°F during the ordinary winter weather in that country without causing excessive pollution of the indoor air He recommends that cow-sheds be kept cool in the autumn and early winter by unrestricted ventilation, so that the animals will retain their winter coats and thus will be in a better condition to withstand the colder temperatures as the winter advances

The evidence accumulated from practical experience in the interval which has elapsed since the early experiments sponsored by the Highland and Agricultural Society of Scotland, confirms that throughout Britain generally *an environmental temperature of about 50°F is probably the most suitable for cowhouses during the winter*

Temperature of Stables. It is no more necessary to maintain a high temperature in stables for horses than it is in cowhouses When working horses have been clipped during the winter, the suppression of excessive loss of body heat can be effected by clothing the animals with rugs together with the provisions of warm, dry bedding, and a sufficiency of food Given these conditions, the temperature of a stable may be ignored, however low it may fall Unrestricted ventilation, which means the free circulation of cold air within a stable or cow-house, will not cause harm to the animals, even to newly-clipped horses, provided they are suitably clothed and fed, and if they be not exposed to cold air entering the building in such a way as to cause a direct draught on any part of their bodies

Temperature of Indoor Piggeries. The optimal thermal conditions

*Speirs (1909). *Trans High and Agri Soc*, Scotland 21, 255.

under which pigs should be housed in indoor piggeries are markedly different from those suitable for horses and cattle, which are provided with comparatively luxuriant coats of hair. The pig, being only sparsely covered with bristle, possesses no adequate external means for the suppression of heat loss from the body surface when the animal is subjected to cold environmental conditions. This fact partly accounts for the detrimental effects observed in pigs which result from exposure of these animals to lowered atmospheric temperatures, and especially to sudden variations in temperature, such as occur in the temperate zones of the world during winter. Further, since the critical temperature of the pig lies between 68°F. and 73°F., it follows that the raising of fattening pigs may be carried on with the greatest economy in feeding costs when environmental temperatures are somewhat above the minimum of this temperature range.

The maintenance of an environmental temperature in the region of 70°F., or higher, in pig houses during winter presents certain difficulties, which so far have not found an effective solution under British conditions. As has already been noted, it is possible to increase the temperature in animal buildings by restricting the ventilation, but the consequent bad effects make the adoption of this method clearly undesirable. The alternative seems, therefore, to be the provision of some system of artificial heating, e.g. by hot water pipes, fuel stoves, electrical or other heating devices.

The unsatisfactory results which many of the "Scandinavian" type pig-houses have given in Great Britain, are to a large degree attributable to the inadequate attention which has been given in their construction to the related problems of ventilation and warmth. Some of the probable causes of failure have been (i.) the use of unlined galvanised iron for outside walls and roofs; (ii.) incorrect types, and wrong placing, of ventilators, giving rise to cold and draughts; (iii.) poorly designed ventilating systems, leading to high humidity and excessive condensation in the buildings; and (iv.) failure to provide insulation beneath concrete floors in the sleeping compartment. A description of the constructional details of this type of pig-house will be found on p. 257. Here it may be noted that one of the essentials of this form of house is provision for carefully controlled temperature, air circulation and atmospheric humidity. In this pig-house as erected in the Scandinavian countries, the entire part occupied by pigs is roofed over with a loft, which serves the dual purpose of a store for food and bedding and as an insulator against extremes of temperature. In most regions of Great Britain a loft is probably unnecessary for the latter purpose; satisfactory insulation will be secured if the house is provided with a ceiling of spaced boarding, which will ensure proper air circu-

lation in normal weather, and which can be strawed over above in severe weather to give additional warmth In the true Scandinavian house, too, air inflow and extraction are exactly controlled by special ducts, and in really cold weather the air is warmed by admission through the jackets of special hot air stoves These precautions are probably unnecessary in the milder climate of southern England, but similar devices might probably be adopted with advantage elsewhere in Great Britain during the winter months Practical evidence from Scandinavia and elsewhere indicates that the cost of heating pig-houses is more than balanced by the saving in food costs and better health of the pigs

ATMOSPHERIC HUMIDITY IN ANIMAL BUILDINGS

Such standards as have been laid down for atmospheric humidity in animal buildings are quite arbitrary Several authors have suggested a relative humidity of 70% at 50°F but Findlay* in his recent work on the ventilation of cattle byres states that "it is impossible to control the relative humidity in a byre or to suggest any attainable minimum for it, but if the ventilation is such that the CO_2 does not exceed 22 parts per 10,000 and the cooling power does not exceed 7 units, the relative humidity is never likely to be so high as to cause discomfort to the cows or damage to the fitments of the byre "

As far as the efficiency of the ventilating system is concerned, it may reasonably be held that the relative humidity in any well ventilated building should not exceed that of the outside air by more than about 5%

DETRIMENTAL EFFECTS OF INADEQUATE VENTILATION

It has already been emphasised that any detrimental effects arising from the keeping of animals in badly ventilated buildings are referable to the combined effects of high environmental temperature and humidity, which lead to the restriction of heat loss from the body The most extreme instance of heat accumulation in the body resulting from these causes is seen in "heat stroke," during which the body temperature may rise to a point at which there is a destructive action on body tissues, and death ensues usually as a result of myocardial failure Whilst the pathology of heat stroke is fairly well understood, there is a dearth of accurate information regarding the effects of sub-maximal degrees of heat accumulation in the body resulting from high temperature and high relative humidity The immediate effects experienced by human subjects exposed to these conditions in badly ventilated rooms include headache, drowsiness,

and mental and physical depression. The more remote effects of prolonged exposure to high atmospheric temperature and humidity are still the subject of considerable surmise. Evidence from tropical or sub-tropical regions of high humidity such as the West Indies, leads to the conclusion that where the day-to-day variability of weather conditions is small, the body tends to lose its adaptability to any unusually marked climatic change without some pathological consequences ensuing.* This fact underlies the danger of "chills" which is so strongly emphasised in handbooks on tropical medicine and hygiene. For the same reason, too great a contrast between indoor and outdoor temperatures in winter-time makes it difficult for the body to become quickly readjusted to the lower external temperatures. There can be little doubt that a similar loss of adaptability to sudden climatic changes occurs when livestock are confined in badly ventilated buildings, in which both temperature and humidity are high. Under such conditions, just as in those of hot and humid tropical regions, the mechanism of reaction to cooling becomes so slow and inadequate that when the animals are exposed to a lowering of atmospheric temperature this may lead to "chilling" with its attendant consequences. For this reason cows should never be turned out of a warm, humid building to stand in a cold, draughty yard whilst the standings are being cleaned out. Where this latter practice is adopted, arrangements should be made to have the cattle out at mid-day, when the outdoor atmospheric temperature in winter is probably at a maximum and the risk of chill, therefore, least. A similar argument applies to turning cattle out of doors in all weathers for the purpose of watering ; the obvious solution in this case is to have water laid on to cowhouses.

Another factor responsible for chilling and its resulting susceptibility to various diseases, e.g. respiratory infections, mastitis, etc., is that horses and cattle housed continuously in warm quarters do not develop the warm winter coat natural to them. Conversely, animals which have been living outdoors soon lose their protective winter coats when placed in such surroundings.

In spite of scientific proof to the contrary, many dairymen persistently hold the erroneous opinion that warmth is necessary for milk production. In support of their contention they bring forward the argument that when a sudden drop in the temperature occurs, as, for instance, may happen in the night with a shift of wind, the yield of milk on the ensuing morning is sometimes less than it would have been had the temperature remained at its higher level. It cannot be denied that such may be the case, but the reason is not that

*See Stone (1941). "Climate and Man." *Yearbook U. S. Dept. Agri.*, pp. 246-261.

the air is too cold, but that cows kept too warm, and in an atmosphere holding too much moisture, are especially susceptible to the chilling effect of fresh, cold air.

Reference has already been made to the difficulties associated with the special problem of maintaining suitable temperatures in large pig-houses without restricting ventilation These difficulties are well illustrated in a careful report by Shanks,* dealing with the causes of high mortality and morbidity amongst pigs in Northern Ireland This worker is of the opinion that the atmospheric temperature of indoor pig-houses should be in the region of 80°F The following quotation from Shanks' report gives an excellent outline of the problems connected with the ventilation and heating of indoor piggeries

"When no outside run is provided so that pigs have to void their excreta inside the building, a temperature of 80°F would result in a very foetid and moist atmosphere Inside drinking bowls would add to the moisture content inside the house, which would be increased still further should wet feeding be practised

In order to obtain a reasonably pure atmosphere in large piggeries without outside runs it is necessary to make a compromise between the temperature of the house and the contamination of the atmosphere with evaporation from the manure and urine Numerous temperature recordings taken in such houses during the colder moths of the year have shown temperatures as low as freezing point and with an average about 55°F On the other hand, in one particular piggery where all means of ventilation were closed in order to raise the temperature to between 76° and 80°F, the atmosphere was so foetid and full of ammonia that it brought tears to the eyes on entering. Under both these conditions the animals were far from healthy In both cases pneumonia and coughs were prevalent In the cold houses the pigs were restless and inclined to huddle together for warmth and they were slow in fattening Tail biting and fighting was not uncommon in such houses In the warm, stuffy house the pigs were more unhealthy Pneumonia was very prevalent and coughing incessant The pigs thrived very badly

Our object was to provide the pigs with a warm, dry house, free from the smell of excreta. To that end each double pen was completely partitioned off from the other houses, yards were provided to each pen so that all excreta was voided in the yards and drinking bowls were placed outside the house to prevent the floor inside the house from being kept damp with spilled water In order to allow the pigs free access to the yards without excessive draughts, swing doors were provided, and as an extra precaution a concrete baffle wall 3ft 6in. high was built inside the house opposite the door To preserve the heat still further an air space was left under the floor and the roof was also provided with an air space Temperature recordings made during one week of exceptionally heavy frost showed a temperature varying from 79° to 81°F during the whole period Maximum and minimum thermometer readings were recorded in this house morning and night for over a year and during that period the maximum temperature recorded was 85°F and the minimum 62°F

*Shanks P L. (1942) Vet Rec 54, 233 235 See also ' A Survey of Pig Hous-ing," by Inglis and Robertson (1951) Emp J Exp Agric 19, 202 215

There were no sudden changes in temperature, the greatest day or night variation being 12°F."

The type of pig-house described by Shanks is stated to have been very satisfactory, and it is indicated that losses from ill-health and disease amongst the pigs were very markedly reduced.

Apart from a lowering of resistance to disease brought about by continued exposure to high environmental temperature and humidity, there are other factors that favour the transmission of various possibly air-borne diseases (tuberculosis, various specific respiratory affections, influenza, foot-and-mouth disease, swine fever, etc.) in badly ventilated buildings. In the presence of an infectious hazard of this kind, it is obvious that the concentration of infective material suspended in the air will be greater when there is little inflow of pure, clean air on the one hand and a low outflow of foul air on the other. Conversely, in a well-ventilated building which is dry and cool there is effective dilution of the foul air, which reduces its infective possibilities. Moreover, since warmth and humidity tend to prolong the viability of pathogenic bacteria while desiccation reduces their chances of survival, their degree of concentration is thus further enhanced in a warm and moist atmosphere.

The optimum indoor conditions for maximum productivity in housed animals are complex, and involve such considerations as species and breed variation, disease, general management and nutrition, as well as atmospheric factors. There is, however, ample evidence from a number of different sources that high environmental temperatures have a depressing effect on productive capacity. Thus with dairy cattle it has been shown under experimental conditions that as the atmospheric temperature increased from 40°F. to 95°F. the average milk production per head dropped from 29 to 17 pounds a day.* This bears out the observations of various workers who have reported that pure-bred European cattle imported into the Tropics seldom attain their potential milk-producing capacity, even when kept on an adequate diet. At high tropical temperatures in Brazil, Rhoad† found that European dairy cattle on balanced rations produced only about 56 per cent. of their apparent capacity. That high quality dairy cows of the European breeds produce best under relatively cool conditions is well illustrated in the results reported by Villegas‡ with Friesian cows in Singapore, which were kept in an air-conditioned shed at a temperature of 70°F. Cows in this shed produced an average of 24 pounds of milk a day as compared with a production of 9 pounds for a similar group of animals in an open, ventilated shed exposed to tropical temperatures.

*Reagan and Richardson (1938). *J. Dairy Science*, 21, 73-79.
†Rhoad (1925). *Proc. Amer. Soc. Anim. Prod.*, 28, 212-214.
‡Villegas (1939). *Philippine Agri.*, 27, 693-725.

Furthermore, it is stated that 58 per cent of the cows in the air-conditioned shed conceived within five months of calving as compared with only 25 per cent in the open shed. It would, therefore, appear that high atmospheric temperature has a lowering effect on reproductive as well as productive efficiency. Daubney* on the basis of his own observations in Kenya and those of other investigators elsewhere concludes that European cattle can be raised without deterioration only in areas where the mean annual temperature does not exceed 65°F and provided that the nutritional plane is adequate. While not directly related to the problems of high temperature and ventilation in buildings, evidence of this kind does indicate the possible deleterious effects of keeping animals in unfavourable surroundings.

VENTILATION REQUIREMENTS

The functions of ventilation in relation to occupied buildings may be enumerated as follows —

(i) The removal of excessive moisture and warmth

(ii) The removal of suspended and diffused impurities

(iii) Provision for a certain degree of air movement

(iv) The accomplishment of the preceding by bringing about an inflow of outside air equal in volume to the foul air removed (air exchange), without causing draught and without unduly lowering the indoor temperature

In times past, many persons responsible for the construction of animal houses approached the subject of ventilation with the idea that the ingress of fresh air into a stable or cow house must be prevented in order that the indoor temperature might be kept high. The modern view is to regard animal houses as necessary evils, if they cannot be dispensed with altogether, the alternative is to make them as little 'house-like' as possible and to keep in mind that what is required in housing is protection from the elements and facility in feeding and attending the animals. Indeed present veterinary opinion favours a departure from the long-established practice of confining animals in closed buildings toward a more wide spread adoption of the open type of accommodation such as open or partially covered yards, paddocks, etc., for all classes of livestock with the exception of fattening pigs. The observations of veterinarians and stockowners would certainly appear to show that under the open air system animals remain healthier and agriculturalists are satisfied that the system is both economically and practically sound. Presumptive Standards of Permissible Air Pollution in Buildings. Since it has been found expedient to keep animals in closed buildings,

*Daubney (1942) E. Afr. Agric. J. 1, 127 141

and as the air in an occupied building can never be as pure as the outside air, it is necessary to form an opinion as to the degree of air pollution that can be allowed without impairing the health or comfort of the animals.

Whilst it is now known that the level of CO_2 in occupied buildings, however inadequate the ventilation may be, is never likely to reach a concentration which is harmful or dangerous to animal life, the CO_2 content may be used, with the reservations previously mentioned, as a comparatively easily determined index of the rate of air exchange between the interior and exterior of a building, *i.e.* of the mechanical efficiency of the ventilating system.

Some of the earliest work in this connection was that of King* who, as a result of observations in North America recommended as a standard for the maximum permissible CO_2 content of the air in animal buildings 16.7 parts per 10,000. In King's view the standard degree of purity for animal houses should not be lower than 96.7%, *i.e.* the air in buildings should not contain more than 3.3% of air once breathed. On this basis he calculated the hourly requirements of fresh air for the different species. Armsby and Kriss, in the work already cited, accepted King's figure for the flow per hour from the known CO_2 excretion of each animal. Their figures, together with those of King, are shown in the table.

Table modified from Armsby and Kriss showing Air Flow required per hour.

Animal	CO_2 produced per hour	Air Flow per hour	Air Flow per hour according to King
	Cubic Feet.	Cubic Feet.	Cubic Feet.
Cow* . . .	5.8	3452	3545
Horse (small) .	3.9	2307	4303
Pig (adult) .	1.3	767	1394

*Average for cows in milk.

Hendrick † and others investigated the condition of the air in a number of cowsheds in Aberdeenshire and found the average amount of CO_2 to be 25 parts per 10,000 but a higher degree of purity, 11 parts per 10,000, was found in two exceptionally well-ventilated sheds. Findlay,‡ as a result of his recent work in Scotland, is of the opinion

*King, F. H. (1908). *Op. cit.*
† Hendrick *et al.* *Trans. High. and Agric. Soc. Scot.*, 1909, 1911, 1913.
‡ Findlay (1948). *Op. cit.*

that King's standard for CO_2 is too difficult to attain and suggests that a rate of air change represented by a standard of 22 parts per 10,000 is sufficiently low and should be attainable in any adequately ventilated byre

Air Exchange and Cubic Space. The satisfactory ventilation of a building depends upon two constructional factors (a) provision for the interchange of air by means of adequate inlets and outlets, and (b) provision of sufficient air space, or cubic capacity, in order that the air change can be effected without causing the air movement to be unpleasant, i e draughty to the animals It will be obvious that a large cubic space per animal, without any means of letting out the respired air and of admitting fresh air would be useless, as it would only be a question of time before the air would become foul, the smaller the air space the more rapidly would the air in the building become foul On the other hand, provision for the free exchange of air without an adequate cubic space would mean that the air in the building would be changed too frequently for comfort It is believed that all domestic animals can stand the total air in a building being changed at least five to eight times every hour,* and it is probable that cattle, whose critical temperature is lower than that of either horses or pigs, can stand a more frequent rate of change than this

Few reliable investigations have been made into this subject and it is therefore impossible to lay down any definite standards either for air flow per hour or for requisite air space In the light of existing knowledge it is only possible to suggest the following approximate figures for the different species —

Animal	Air flow in cubic feet per hour	Requisite Air space in cubic feet
Dairy cows	4 000	600-800
Fattening cattle	4 000	600-800
H D horses	4 000	800
Sows and Boars	4 000	800
Fattening pigs	700	140
Dogs	250-500	50-100
	200	40

*The Animals (Sea Transport) Order of 1930 requires that in ships carrying cattle "separate ventilation shall be provided for each compartment on each deck, and in addition to any ventilation obtained by means of the hatchways there shall be for each enclosed compartment, mechanical means of ventilation, by electric fans or otherwise of sufficient capacity entirely to change the air once every three minutes" Experience has shown that cattle on board ship can stand this frequent air change, it is necessary because of the restricted cubic space

Calculation of Cubic Air Capacity of Buildings. It has been indicated in the preceding paragraphs that the cubic air space available to animals in buildings must be sufficient to allow of a satisfactory rate of air exchange in the indoor atmosphere without the causation of too draughty conditions. In estimating the effective cubic air space of buildings, it is customary to omit from consideration any height above 16 feet from ground level. Above this limit the air is useless for respiratory purposes, and since this air may become cooled before reaching the outlets at the ridge, and thus tend to fall, too great an air space above the 16 feet level may lead to undesirable downdraughts. In calculating the cubic capacity of a building, therefore, include on the height up to, but not beyond, 16 feet. The cubic air capacity of the usual type of ridge building used for the housing of animals is obtained by multiplying length × span (breadth) × average height: (*i.e.* height from floor to a point mid-way between eaves and ridge).

If extreme accuracy is wanted in calculating the cubic air space of buildings, the amount of space occupied by the animals themselves may be taken into account. From the total air space of a building arrived at from its dimensions, there must then be subtracted the amount of air space occupied by the animals present. The following are the volumes per head usually quoted for the various domesticated animals : heavy draught horse, 30 cu. ft. : larger breeds of dairy cow, 25 cu. ft. : and Channel Island breeds, 20 cu. ft. : and about 8-10 cu. ft. for each adult pig.

Floor Space. It may be taken that a good working rule for most animal houses is to construct buildings so that the number of superfical feet in the floor is not less than one-fourteenth to one-fifteenth of the total number of cubic feet of air space in the building. For example, in a cowshed with 800 cubic feet of air space per animal, an effective height of 16 feet will give a floor area per cow of 50 sq. ft., which is about the minimum usually recommended for a single-range cowhouse (45 sq. ft. per cow in a double-range house).

THE MECHANICS OF AIR FLOW AND VENTILATION

Ventilation implies the methodical and uninterrupted exchange of fresh air for foul air, so that at no time does atmospheric pollution in a building exceed a standard. Ventilation in the correct sense, is thus a continuous, not an intermittent, process.

Either natural or artificial means may be employed to ventilate buildings, the former being almost always adopted for animal habita-

tions In the natural method, advantage is taken of the physical laws that govern gas diffusion and movement of air, and although various contrivances may be used to facilitate the air exchange, the adoption of such devices does not constitute a mechanical or artificial system. An artificial method of ventilation is one in which mechanical power is used to force air into, or draw air out of, a building A similar effect is also obtained by the installation of artificial heating in a building

Natural Ventilation. The two chief natural means by which the air is kept pure and healthy are (i) movement of masses of air of unequal temperature, and (ii) diffusion of gases of different densities In a building the CO_2 and CH_4 (methane) excreted by animals become diffused through the atmosphere, and thus do not concentrate around their source of production. The natural diffusion of gases is, therefore, an important aid toward ventilation by ensuring a certain uniformity in the composition of the air in a building Chemical examinations of the air in stables and byres have shown that the percentage of CO_2 varies very little in the different sections of these buildings

For practical purposes the actual passage of air into and from, a building may be considered to depend upon the movements of volumes of air at different temperatures, the rate at which these move being known as the *air velocity,*

A wind is the result of the upward passage into the higher atmospheric strata of heated and less dense air, the wind being a body of cooler and denser air flowing in to fill the space thus created Exactly the same process takes place in a building occupied by animals whose body temperatures are higher than the air surrounding them. As the air becomes warmed by the excess body heat lost by radiation and convection, it becomes less dense, rises, and thus gives rise to an upward current Provision should, therefore, be made for the escape of this warmed air from the upper part of the building, the best place being at the highest point, i e the ridge On the other hand the best site for the inlet of fresh, cool air would appear to be at a low level, so that a complete circulation of air at all levels in the building is ensured If the air inlets are placed high in the wall, e g at the eaves (approximately 8 ft from ground level), this will tend to give rise to pockets of stagnant air at lower levels in the building In the case of cowsheds and stables, the most suitable place is probably just below the animals' heads, or at the top of the mangers, i e at from 1½ to 2½ ft. above floor level There the fresh air is most readily available for the animals

The passage of air into and from a building, however, is not

solely dependent upon the degree to which the inside air is heated. Wind acting from the outside is a most powerful ventilating force, and its action is two-fold. It drives fresh air into a building through any available opening, mixes with and dilutes the vitiated air and forces it on and out through openings on the other, or lee, side. This is called the perflating action of the wind. The second power, and one of great importance, is the aspirating effect which is set up when wind passes across or through any opening. If wind passes in at one window and out at another on the opposite side, it draws air from all points as it passes. Similarly, when it blows across openings in the roof it aspirates air out of the building and so sets up other currents which flow in to fill the space formerly occupied by that which has escaped. As the external atmosphere is very rarely still in this country, there is nearly always a certain movement of air into and from a building due to the action of the wind. A condition of absolute calm, however, does not necessarily imply that no air exchange will take place. So long as the temperature in a building is higher than that outside there will be a constant outflow of hot air and an inward flow of cool air, though at a slower rate than would be the case if wind were present.

From what has been said, it will be clear that every system of ventilation must include (i) provision for the escape of foul air and (ii) provision for the inlet of fresh air. (But cf. Findlay (1948), op. cit.)

Size of Air Inlets and Outlets. Wind blowing at the rate of three miles per hour, which is practically a calm, will introduce into a building 110 cubic feet of air per hour for every square inch of inlet. Very rarely does the movement of air remain at such a low speed for any length of time, as the average velocity of the wind in this country is approximately 15 miles per hour. Provision for the inlet and outlet of air should be such as will permit satisfactory ventilation when the wind is scarcely perceptible. If, therefore, facilities for air exchange are to be provided on this basis the inlet and outlet areas for the different animals should be as follows :—

Inlet and outlet Area required per Head with Wind at 3 m.p.h.

	*Cubic feet of Air per hour	Inlet and outlet area in square inches
Cows	4000	36
Horses	4000	36
Pigs	250-700	2.5-6
Dogs	200	1.8

* See table, page 136.
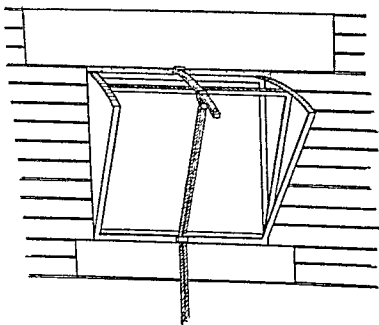
Fig. 33—Hopper Window fitted with a quadrant.
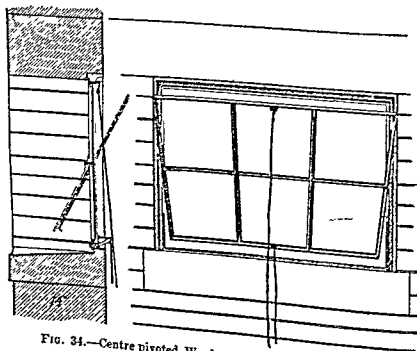
Fig. 34.—Centre pivoted Window. Section and elevation.

The inlet area required can be readily ascertained by dividing the volume of air to be supplied hourly by the volume of air passing through each square inch of inlet when the wind is blowing at three m.p.h., that is, 110 cubic feet. But the wind force is usually much greater than this, and if the maximum inlet area required were to be in the form of a number of permanent openings such, for example, as drain pipes passing through the wall, which is a common method of ventilating cowsheds in Scotland, an excessive quantity of cold air would enter the building on windy days. In fact, where such large uncontrollable openings exist they are usually to be found stuffed with straw. It is advisable therefore, to have a proportion of the inlet area in all animal buildings in the form of fixed openings, and the remainder controllable so that they can be opened or shut as the need arises. For obvious reasons it is not wise to have all the inlets capable of being closed. The ventilation of any animal building would probably be satisfactory if the fixed inlet area were one-fifth of the maximum required, this being based on an average wind force of fifteen m.p.h. For example, in the case of a cow or a horse the maximum inlet area required per head is 36 square inches; therefore the *fixed* inlet area would be

$$\frac{4000}{550} = 7.3 \text{ square inches.}$$

This could be provided by a three-inch drain pipe, which would give an inlet area of 7.06 square inches; a four-inch drain pipe would give an inlet area of 12.5 square inches. A four-inch pipe would therefore be sufficient for all practical purposes for each pair of horses or pair of cows. This leaves approximately twenty-nine square inches to be provided by movable vents such as hopper windows. A window two feet long and opening four inches would give an inlet area of ninety-six square inches; therefore two windows in the wall (each of these dimensions) would be sufficient for seven cows, or six windows in the wall for every ten pairs of cows.

Inlet Ventilators. There are various forms of inlet ventilator, of which the following are the chief types :—*Wall windows, direct inlet pipes and boxes, air bricks, and metal gratings.*

Windows. Wall windows usually serve the dual purpose of lighting and ventilating. The best type for animal houses is the *hopper* window. This window is hinged at the bottom and opens inwards as shown in Fig. 33. At the sides are guards to prevent down-draught. The incoming air is thus directed upwards and spreads out fanwise before

falling behind the animals   Hopper windows should be adjustable so that they can be partly closed when necessary   A good window for byres is one on the hopper principle that will lift right out of the frame work, thus leaving a clear open space on hot days   If wall windows form the only ventilating means in a stable it must be remembered that only those on the windward side will act as inlets, then the *minimum* ventilating area of each window for each horse or cow must be doubled   This, of course, applies to all forms of wall ventilators

Horizontally centre pivoted windows (Fig 34) are satisfactory in sheltered parts of a building, but are not so useful as the hopper
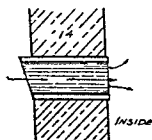
Fig 35 — A Dram Pipe form ing a direct air inlet.
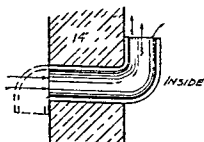
Fig 36 — A Bent Pipe Air Inlet in which the air is directed upwards   An alternative method is to bend the pipe downwards on the outside of the building as shown by the broken l nes in order to check the force of the incoming air

type for exposed positions, because with a wind of any force the incoming air cannot be properly controlled, with the consequence that such windows are more often kept shut than open

Direct Inlet Pipes and Boxes.   Very simple and effective air inlets for cow byres are ordinary fireclay drain pipes of about 4 inch diameter   These may be set level through the wall (Foig 35) or placed at an angle that gives the incoming air an upward trend   In the west of Scotland it is the common custom to put one drain pipe in between each pair of cows, they are placed level and just above the food trough   In some byres they are put on a level with the cows' heads when they are standing   In some instances bent pipes are used in order to break the force of the incoming air (Fig 36)

Inlet boxes are sometimes fitted with regulating valves (Fig 37)

ir Bricks.   Air bricks as their name suggests, are perforated bricks, or the admission of air   They are of various designs and sizes theoretically the inlet area is considered to be one-third of the brick

face area.   When the bricks have been in place for any length of time they get partly blocked with dust and cobwebs.   One type of brick is constructed so that the incoming air is given an upward trend. Another type has the holes on the outside of the building smaller than those inside, so that as the air enters its force is reduced.

Metal Gratings.   A simple metal grating, fitted flush with the outside face of the wall, forms a good and efficient type of air inlet.   The boundaries of the recess in the wall behind the grating should be smooth rendered in cement and sloped or bevelled so as to afford less
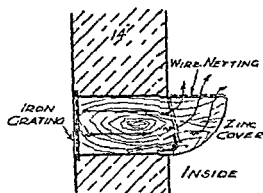
FIG. 37.—A Box Air Inlet fitted with a grating on the outside and a regulating valve on the inside.   The incoming air is directed upwards.
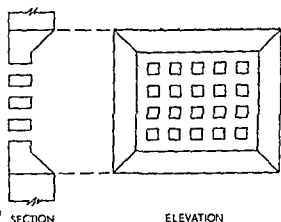
FIG. 38.—One type of grating.

SECTION   ELEVATION

lodgment for dust.   These metal gratings are obtainable in standard sizes of from 12 to 18 sq. in. (Fig. 38).

Sometimes a second grating is fitted flush with the inside wall face, but this is unnecessary and is undesirable because the space between the two gratings cannot be cleaned out easily.

An inlet grating fitted with an adjustable or "hit-and-miss" device for regulating the flow of air is available.

Outlet Ventilators.   For reasons already described these should be placed where possible at the highest point of the building, i.e. the roof apex.   Satisfactory outlet ventilation may be secured by the following means :   *continuous opening in the ridge; adjustable ridge opening; ridge tiles; and louvre ventilators.*

Continuous Ridge Opening.   One of the best forms of outlet for cowsheds in an open ridge the full length of the building.   By this provision, the escape of the warmed air, rising upwards, is hastened by the aspirating influence of any wind passing over the roof ridge.   The
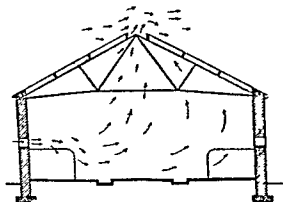
FIG 39 —A Double Cow-shed with a perma
nently open ridge for the escape of foul
air The air inlets are drain p pes set
at right angles to the wall just above the
cows heads

physical explanation of this
is clearly indicated by the
arrows in Figure 39

It should be noted that
the open ridge system is
only possible in buildings
without a loft A perma
nently open ridge such as
described has been found to
be both cheap and efficient
For byres the width of open
ridge must be calculated in
accordance with the provi
sions laid down on page 139,
4 to 6 inches will usually be found satisfactory for these buildings

Adjustable Ridge Opening An improvement on a permanently
open ridge especially for a building in an exposed position, is the
method sometimes known as *Findlay's System* It can be used for
byres stables or other animal houses where there is not a room or loft
above the animal accommodation The object of the system is to
provide for the free escape of foul air at the most suitable point,
namely the roof apex in combination with efficient lighting of the
building. Throughout the entire length of the building both sides of
the ridge open upwards as shown in Figure 40 This is accomplished
by finishing the roof boarding and slating about 1 foot short of the
ridge at each side of the roof and filling the opening with glazed
sashes which, being hinged at the lower edge open upwards as shown
in the figure the frames of the sashes may be made of wood or metal
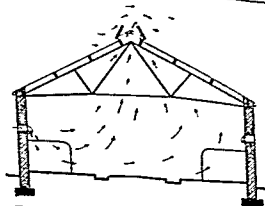
FIG 40 —Findlay s method of ventilating a
cow-shed. For d tails of construction see
the text.

This will give a ventilating
opening about 1 foot 8 in
ches wide with a roof built
to a pitch of 30 degrees
and provided that the sides
of any upper purlins are
kept perpendicular The
sashes are connected with
a lever which by one
movement can easily regu
late the opening to the
desired width. When both
sides of the ridge are open
the wind striking on the

weather side is directed upwards, passes across the opening and, by producing an aspirating effect, assists the heated and foul air to escape. The roof timbers that are exposed to the open are protected from the weather by covering them with zinc or bitumastic sheeting. If so desired, the sashes can be divided into two or more sections and the two sides of the building be made to operate independently.
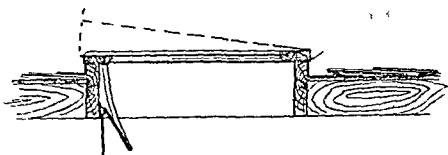
FIG. 41.—A Roof Skylight with a quadrant.
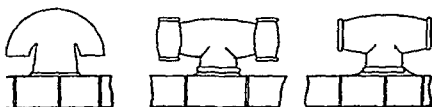
FIG. 42.—Three types of Fireclay Ridge Ventilators.
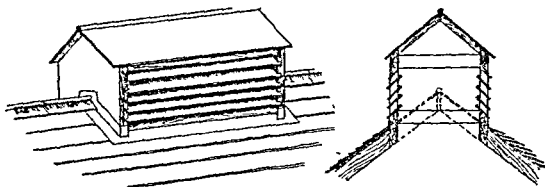
FIG. 43.—Illustration and section of a Louvre-Board Air Outlet Box fitted to the roof bridge.

Roof Lights or Skylights. The adjustable roof light or skylight, situated about the middle of the roof slope, is most unsatisfactory as a ventilating appliance. When open, see Fig. 41, the wind blows inwards and downwards causing cold "air-drops" and, if there is no ridge outlet, gives rise to a pocket of warm foul air in the upper part of the roof.

Ridge Titles. As a simple means of outlet ventilation, one in every two or three ridge tiles is often "horsed" or raised, or turned at right angles. This method will only be effective provided the boarding in the roof does not check the outward escape of air. Specially designed ridge tiles for use with most of the common roofing materials are available.

Fireclay Ridge Outlets. These are common on old-fashioned and on many new but badly designed byres and stables. They take a form similar to the ordinary fireclay T chimney-can as shown in Figure 42. They are almost useless because of their small outlet area.

A series of 4-inch drain pipes placed at intervals along the roof apex provided a simple and efficient means of outlet ventilation.
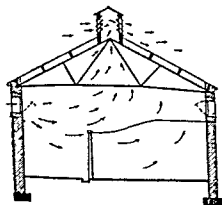
Fig. 44.—Showing the method of ventilating a stable with hopper inlet windows and a louvre board outlet fitted on the roof ridge.

Louvre-board Ventilators. This type of air outlet terminal, if properly constructed, is good and effective. Probably the neglect of this ventilator, combined with improper position or design, is the cause of its frequent condemnation. It consists of any form of covered frame or box placed on the ridge of a roof, the sides of the box or framing being filled with a series of superimposed sloping boards or metal or glass plates set at regular spaces in such manner as will permit of the escape of foul air and prevent the ingress of rain. The louvre-boards should be set at an angle of 50 or 60 degrees to the horizontal. By the relative proportion of the width of board and the spacing of same, rain can be excluded under any but extraordinary conditions. It is advisable to have a weather fillet nailed to the upper edge of each louvre-board to form a water check. In the case of metal plates the upper edge may be turned up for this purpose. The boards or plates are let into grooves formed in the framing posts. The perflating action of the wind passing through the louvred ventilator with its consequent aspirating effect is indicated in the figure. Adjustable or movable louvres are to be condemned as they are often neglected and readily get out of order.

Extraction Cowls. A variety of extractors are made and sold as proprietary articles. The qualities claimed for them are that they

prevent down-draught and accentuate the aspirating action in the duct or shaft which they surmount.

Outlet Shafts. Outlet shafts are often employed in lofted buildings and may be circular or rectangular in section, the former being the better, and more effective and economical. The material of construction may be zinc, galvanised or black iron. The combined sectional area of the shafts must be designed to accord with the required air changes previously indicated. The following points should be noted :—The greater the length of the shaft the greater is its extracting power. Bends in shafts retard the air current, but where they are unavoidable the diameter at the bend should be increased. Shafts should not be exposed to the open air more than is necessary, otherwise, in cold weather, the extracting power will be retarded.

Ventilation of Double-Storied Stables. It is not always possible to build stables with only one storey, and in cities it was often necessary to stable horses on two or three floors one above the other, the standings being arranged in double ranges. The most suitable method of ventilating such stables is by the use of windows of the hopper type on each side of the building, one being placed at the head of each horse's stall ; the windows on the weather side will act as inlets and those on the lee side solely as outlets, thus producing a cross ventilation. In order to get a satisfactory air exchange, windows of a larger size than those ordinarily used in the open ridge type of building must be installed. The installation of outlet shafts as above described should be effected where possible.

Fig. 45.—The Ventilation of a double-storey or lofted stable. The inlet of fresh air is provided for by hopper windows. The foul air escapes through flues either as shown by *A* to avoid breaking the loft or overhead stable space, or *B*, which is preferable, by a direct flue carried straight up to the roof ridge. The flues are surmounted by suitable extraction cowls.

The King System.* This method, evolved by F. H. King in 1889, is used to a considerable extent in North America, where the severity of the winter

* *The King System of Ventilation, Univ. Wiscon. Agric. Exp. Station Bull.*, 164, 1908.

climate has favoured the single comprehensive type of farm building, or 'barn,' provided with two or three stories (See Fig 46) The outlet ventilating system consists of two sets of flues one of which provides the fresh air, while the other furnishes an escape for the vitiated air The following instructions are taken from the official bulletin —The inlet or fresh air flues should be placed in the exterior walls of the building and not more than 10 feet apart, the greater the number the more effective the ventilation, since they enable the fresh air to displace the foul air more rapidly The outlet may include one or more flues but should be located so as to provide the quickest means of removing the foul air The outlet shaft is carried down to near the floor The objects of placing the intake of the extraction shaft at such a low level are given as follows —(1) To remove the CO_2 and other waste products of respiration which settle near the floor (2) To dispose of the cold air in winter weather rather than the warm The coldest air in a room is at the floor and the warmest at the ceiling. Fresh air is
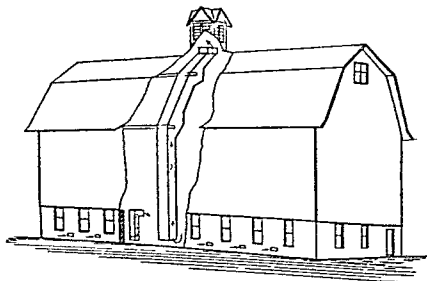
Fig 46 —The king system of ventilating cow barns as adopted in America.
(By permission from the Wisconsin Experiment Station Bulletin 164.)

taken in through small flues placed at intervals along the side walls as shown in the figure The outside opening is placed near the ground line, but may be higher in the wall if found necessary It should not, however, be placed less than 3 feet below the ceiling to guard against the warm air flowing outward The inner opening of the intake shaft is placed just under the ceiling and may be provided with a movable shutter to control the amount of air passing in The object of having the air-inlet opening at such a high level is that the incoming air will mingle with the warm air found at the ceiling and become warmed before it settles to the floor It is pointed out that for this system of ventilation to be successful the ceiling and walls must be practically air tight. The construction of the foul air flues is of importance, as faulty construction has led to failure in the system. They should be as straight as possible, as every turn of bend greatly reduces the carrying capacity by increasing the friction of the moving air on the flue A good ventilating flue should have the same qualities as a good chimney It should

rise above the highest part of the roof, so as to receive the full force of the wind. Where only one flue is used it should be placed as near the centre of the building as possible. Doors and windows must fit well. Foul air flues should be air-tight and non-conductors of heat and cold. The lower opening should be about 1 foot above the floor level, and with as few bends as possible pass up to a height of at least 25 feet, and should always be 2 or 3 feet above the ridge of the roof or of any adjoining roof.

The King system of ventilation is unnecessary with the temperate climate of Great Britain.

Mechanical Ventilation. Mechanical ventilation is adopted where for some reason a purely natural method is in itself either inefficient or impracticable. There are two methods :—(1) the *plenum* method whereby hot or cold air is forced into a building through ducts by means either of a propeller or cased fan driven by motive power; (2) the *vacuum* or *extraction* method whereby air is sucked out of a building by a fan. The extraction method has been found to be more efficient under varying conditions than has the plenum system. Mechanical ventilation is used in mines and in ships carrying livestock. It is impossible to ventilate the holds of ships in which livestock are carried without adopting some mechanical method of drawing out the foul air and admitting fresh air. This is effected by placing an electrically-driven intake fan at one end of the hold and an exhaust fan at the other end. No general rule can be laid down regarding the size of fan to be installed. A detailed analysis of the circuit through which the desired air current has to be maintained requires to be made in each particular case. It is important to note that a system will break down if doorways, etc., are left open, particularly near the exhaust fan. A well-designed mechanical ventilating system, if properly looked after, is very efficient and is found to work excellently on cattle boats, intensive poultry house, etc.

INVESTIGATION OF THE CONDITION OF THE ATMOSPHERE IN ANIMAL BUILDINGS

Any inquiry into the condition of the atmosphere within animal buildings, made for the purpose of assessing the efficiency of the ventilating system should, as far as possible, be conducted during average weather conditions, and always after the particular building under investigation has been fully occupied for some hours.

An impression of the atmospheric condition obtaining within a building as compared with that of the outdoor air is sometimes readily available to an observer on first entering the building. For example, the presence of characteristic animal odours will be easily noticeable, as will also be any marked differences between the outdoor and indoor temperatures. It may also be noted whether the indoor

atmosphere conveys a sense of humidity and oppressiveness on the one hand, or whether of relative dryness and freshness on the other. Objective evidence of excessive humidity in the form of condensation may be looked for on the walls, on window panes, and on any metal work forming part of the interior of buildings or of its fittings   The presence of such moisture in the air of buildings, however, is not in itself a reliable indication of the ventilation when the outside air is also heavily charged with moisture   If on the other hand, the atmosphere inside a building is very humid on a cool dry day, then it may be assumed that the ventilation is faulty

Whilst useful preliminary information about the state of the atmosphere in occupied buildings may be given by evidence of the kind noted in the preceding paragraph, methods which are less liable to individual variation on the part of different observers must be employed if accurate data are to be obtained regarding the efficiency of different ventilating systems, and particularly in so far as the collection of reliable information on the comparative effects of environmental conditions on the comfort and productivity of livestock are concerned. Apart from the somewhat scanty data which have been cited elsewhere in this Section, there is not at the present time any very useful or generally applicable indications of the indoor, environmental conditions of warmth and humidity which can be regarded as being the most suitable for the different classes of livestock kept in Great Britain. Considerable investigational work is, therefore, urgently necessary in which the results of instrumental measurements are capable of being related to the health and productivity of animals maintained under given sets of conditions   In this connection it is of interest to note the parallel conclusion arrived at by the Committee on Farm Buildings* —"The factors on which reliable evidence is specially necessary include influence of air temperature and floor temperature on bodily health and comfort; control of humidity in pig and other stock houses and the effects of humidity on health, thermal insulation of farm buildings, the general problem of ventilation and in particular, necessary air space allowances and the avoidance of draughts"

THE MEASUREMENT OF INDOOR ENVIRONMENTAL CONDITIONS

It has already been pointed out that the primary function of ventilation in relation to buildings is the removal of excessive warmth from the vicinity of animals or people occupying the buildings   This also implies that an indication of the efficiency of the ventilation in

*See *Farm Buildings*   Post War Building Studies No 17 H.M.S O London :
1945

any particular building may be obtained from the measurement of the *environmental warmth* existing within that building. In order to obtain as complete as possible an assessment of environmental warmth, four separate thermal factors—the temperature, humidity and rate of movement of the air, and radiation from the surroundings —must be taken into account. A short account of the instruments and methods which are used for measuring each of these factors is given below.*

Air Temperature. The temperature of the air is commonly measured by means of the mercury-in-glass thermometer. When a record of the extremes of the temperature change during a given period is required, a maximum and minimum thermometer must be used. In animal habitations the thermometer should be hung clear of the animals' exhalations, and also not in the direct flow of air entering a building.

Atmospheric Humidity. The most satisfactory method of measuring the humidity of the air in a given situation is by means of the whirling hygrometer, and then from the observed temperatures of the wet- and dry-bulbs to read off the humidity from suitable tables. The dry-bulb thermometer gives the air temperature, and unless the air is completely saturated with water vapour the wet-bulb instrument registers below air temperature. The drier the air, the more rapidly is water evaporated from the wet-bulb, and the more is that bulb cooled. Hence, at any given air temperature the difference between the dry- and wet-bulb temperatures increases as the humidity of the air diminishes.

The *Whirling Hygrometer* (or sling psychrometer) is now regarded as a more accurate instrument than hygrometers of the Mason type, in which the wet-bulb temperature is recorded in relatively stagnant air. For accurate results the air must be moved rapidly over the thermometer bulbs, and with the whirling hygrometer this condition can be fulfilled. This instrument consists of a pair of thermometers mounted in a frame which is provided with a handle (Fig. 47). By rotating the instrument about the handle, like a rattle, the thermometers can be whirled rapidly so that their bulbs pass through the air at a considerable velocity. The bulb of one of the thermometers is covered with thin muslin, and this is kept wet by the wick leading to the reservoir containing distilled water. Rapid whirling immediately before the thermometers are read is essential. The air velocity, or the

*For a more complete description of these instruments and their use see M.R.C. War Memorandum No. 17, *Environmental Warmth and its Measurement* by T. Bedford. H.M.S.O. London : 1946.
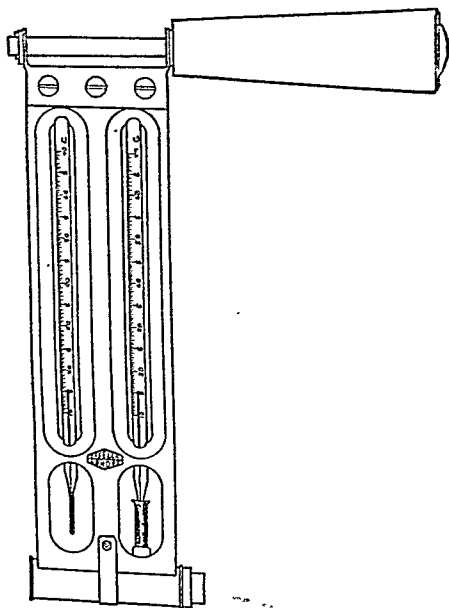
Fig. 47.—The Whirling Hygrometer.

velocity of the bulb of the whirled thermometer relative to the air, should be of the order of 600 ft. per minute.

The data and tables used in connection with Mason's wet and dry bulb thermometer have been computed for relatively still air, and they must not be used with the sling psychrometer. Separate psychrometric tables are available for use with the latter instrument. (*Psychrometric Tables for obtaining the Vapour Pressure, Relative Humidity, and Temperature of the Dew Point*, by C. F. Marvin : Weather Bureau, U. S. Department of Commerce.)

In making an observation using the whirling hygrometer first see that the muslin covering the wet bulb is thoroughly wet. The instrument is then whirled as rapidly as possible for about 30 seconds, stopped, and the wet-bulb read immediately. Repeat whirling until two successive readings of the wet-bulb temperature agree very closely, thus showing that the minimum temperature of the wet-bulb has been reached. This reading is recorded, as also is the dry-bulb temperature. It is very important that the wet-bulb temperature be read first, immediately after whirling has ceased, otherwise its temperature will tend to rise. The relative humidity of the air can be ascertained from the psychrometric tables from a knowledge of the difference between the wet- and dry-bulb temperatures at any given air temperature.

Air Velocity. Various instruments are utilised for measuring the speed of air movement in different types of situation. A convenient *instrument for measuring the velocity in the air of a room or building,* for the assessment of the warmth of the environment, is the kata thermometer.

The Kata Thermometer. The kata thermometer was devised by Sir Leonard Hill with the object of measuring the cooling power of the air and so providing an indication of heat loss from the body. This instrument in its original form was an alcohol thermometer with a large bulb (approx. 4 cm. long and 2 cm. in diameter) of polished glass, the contained alcohol being coloured red, and having on the stem graduations at 95°F. and 100°F. An improved type designed for use in the presence of much radiant heat is *the high temperature silvered kata thermometer*, which has the bulb coated with polished silver, and has graduations on the stem indicating either 125° and 130°F., or 145° and 150°F. From observations of the rate of heat loss from any of these instruments the "cooling power" of the air may be calculated, and from the cooling power and the temperature of the air, the speed of air movement (or air velocity) can then be obtained.

The Kata thermometer is now used only for the measurement of air velocities. Some years ago, the original type of kata thermometer,

with polished glass bulb and a cooling range of 100°-95°, was used as an index of the warmth of the environment It was considered that the cooling power as measured by this instrument (the "dry kata cooling power") gave a measure of the heat dissipation from the human body by radiation and convection, and that the physiological effects of cool or temperate environments were thus measured More recent work has shown this assumption to be unwarranted, and for that reason *the use of the kata thermometer is now confined to the measurement of air velocity* *

It was also at one time advocated that in hot environments observations should be made with the 100°-95° kata thermometer when its bulb was covered with a wet finger stall so that it became a wet-bulb instrument. The "wet kata cooling power" thus measured was influenced by the humidity of the atmosphere as well as by radiation and convection, and it was thought that it indicated the physiological effects of hot environments in which much of the heat loss from the body takes place by evaporation *It is now known that wet kata cooling power is not a reliable index of warmth, and that it may be misleading* * The kata thermometer should not be used as a wet-bulb instrument

Although the kata thermometer was designed for use in human dwellings, it will be found of service in connection with ventilation problems in animal buildings, cattle boats, etc To get the correct picture of the air movement in a building, observations should be taken in different places and at different levels, e g, at the body level of animals, and near the floor where draught is most frequently encountered It is useful for detecting either pockets of stagnant air or draughty positions In this connection it would be useful for determining for instance whether draughts from badly fitting doors, etc, fall on the udders of recumbent cows

†Findlay (1948) suggests a dry kata cooling owerp of 7 as indicative of good ventilation

METHOD OF USING THE KATA THERMOMETER FOR MEASURING AIR VELOCITY

First, immerse the bulb in hot water until the spirit rises about half way up the top bulb and the column is free from bubbles Wipe the bulb *dry* with a clean, absorbent cloth. Now suspend the instrument in the position where the observation is required, it may be held in the hand at arm's length from the body, but is better suspended in a clamp or by a short string It must not be allowed to swing. Then, as the thermometer cools, take the time (in seconds) occupied by the meniscus in falling from the upper graduation

*See Bedford (1946), *op cit*
† Findlay (1948) *op cit*

to the lower, *i.e.* from the 100° mark to the 95° mark : a stop watch should be used for this purpose. Three to five readings should be taken. If the times correspond very closely, three readings are enough, but if they are variable five should be taken. The average of these cooling times is then taken. To get a correct picture of the air velocity in a building, observations should be taken not only in different places, but at different levels, *e.g.* at the body level of animals, and at floor level where draught is most frequently encountered.

The next step is to claculate the air velocity. For each separate instrument the manufacturer determines what is known as the kata factor. This factor preceded by the letter F., is etched on the stem of the thermometer, thus :—"F. 480". When the factor is divided by the average cooling time in seconds, the quotient gives the cooling power expressed in millicalories per sq. cm. per second (1,000 millicalories—1 gm. calorie).

In the computation of results, much arithmetical work can be avoided by the use of special kata formulae or charts. Separate charts have been constructed for the different cooling ranges of the various types of kata thermometer, and care must be taken to see that the appropriate chart is used; use of the wrong chart will cause serious error.

The following readings were taken by the author (Linton) in winter in three badly-ventilated cowsheds on one farm, and, for the purpose of supplying a contrast, in two well-ventilated sheds, one of which was a modern building housing tubercle-free cows for the production of Certified milk. The observations were made during the afternoon when the outside temperature was 34.5° F. on the dry bulb and 32.5° F. on the wet bulb; the relative humidity was 80 per cent.

Farm No. 1.

Cowshed 1. This building held 12 cows, each stall being occupied. The atmosphere was oppressive and stuffy and there was obviously an excessive amount of moisture in the air as water was to be seen dripping from the walls and ironwork.

Dry bulb	...	...	57.0° F.
Wet bulb	...	...	56.0° F.
Relative humidity	...	93.5 per cent.	
Dry kata	...	...	7.66 4 feet 6 inches from the ground behind the cows.
„ „	...	...	7.66 2 inches from the ground behind the cows near a door.

Cowshed 2 housed 11 cows, all the stalls being occupied. The atmosphere was oppressive, but the doors fitted badly and the place was draughty at a low level.

Dry bulb	...	...	54.5° F.
Wet bulb	...	...	52.5° F.
Relative humidity	...	86.7 per cent.	
Dry kata	...	...	7.36 4 feet 6 inches from ground behind cows.
„ „	...	...	10.22 2 inches above ground over manure channel by the door.
„ „	...	...	13.94 2 inches above ground in direct draught from the door and close to a cow's udder.

Cowshed 3 housed 19 cows, all the stalls being occupied. The atmosphere was very heavy and oppressive and there was a definite smell of ammonia.

Dry bulb	...	...	58.5° F.
Wet bulb	...	...	56.0° F.
Relative humidity	...	84.6 per cent.	

LIGHT

The beneficial influence of natural daylight on the health and well being of both man and animals is now generally recognised   In view of the natural growth promoting properties of the sun's rays, e g in relation to the synthesis of vitamin D, it is of especial importance that all young animals should have access to an adequate amount of direct sunlight   This latter fact still does not appear to be as widely known as it ought to be amongst dairy farmers, pig keepers and poultry rearers who, either through ignorance or because of other reasons frequently keep their young stock in dark, damp and squalid premises   It is not surprising that under such conditions the morbidity and mortality incidence in these animals is high.

In the human subject, the psychological effect of good natural lighting may be very marked under certain conditions , for example, it has been observed in factories that when precision work has to be done by artificial light there is frequently a falling off of output as compared with that under conditions of natural lighting, even although the intensity of illumination may be approximately the same for the two methods of lighting   The direct psychological effects of light on domesticated animals are not known, but that light does indirectly influence the conditioning of functional behaviour in most species seems to be now generally accepted   For example, it is now well established that there is a significant relationship between the length and intensity of light, whether natural or artificial, and certain phases of the reproductive cycle in some species of mammals and birds   It is now known, for instance, that the onset of the sexual season in the ewe is a response to decreasing amounts of daylight *

In laying hens, egg production can be influenced considerably by the amount of light to which the birds are subjected   Under the influence of light rays follicle stimulating hormone is produced by the pituitary gland and egg production is thus stimulated   For maximum winter egg production a period of thirteen or fourteen hours of light (daylight plus artificial light) is considered to be the optimum   It should be noted that this has little or no effect on the total egg production throughout the year and merely represents an increase during the winter months with a corresponding reduction during the rest of the laying period

Direct sunlight, in addition to its health promoting properties in the animal body, has also a germicidal action, which is partly due

*Yeates, N T M (1949) *J Agric. Sci*, 39, 1-43

to its ultra-violet rays and partly to the dehydrating effects of its thermal rays on bacteria. Thus, tubercle bacilli when spread in a thin layer are destroyed in a few hours if exposed to the direct rays of the sun; pathogenic streptococci and staphylococci are killed even more readily than tubercle bacilli by sunlight. Ultra-violet rays, however, have little penetrating power and do not pass through ordinary window-glass, so that the germicidal action of sunlight does not, for all practical purposes, operate in the ordinary type of "closed" animal habitation. In this connection, the importance of adequate lighting in animal buildings is that it facilitates cleanliness, on the principle that "dirt unseen is dirt left undisturbed." Lighting thus becomes a material factor in the practice of hygiene, as well as a necessary provision in efficient management. As an aid to better lighting and cleanliness, the upper part of the walls and the ceiling in animal buildings should be white.

LIGHTING OF ANIMAL BUILDINGS

Natural Lighting. Animal habitations should be sited and designed with a view to obtaining the greatest possible amount of natural illumination. Generally speaking, the placing of animal buildings, such as double-range cowsheds and large piggeries, with their long axes in a north-south direction ensures the admission of the maximum amount of sunlight during daytime. This orientation also provides that one end only of a building directly faces the northerly, and therefore colder, aspect. In the case of a dairy cowshed, the milk room would be located at this northern end of the building, in the coolest position and one which affords northerly light.

The most efficient form of natural illumination is by means of some type of roof lighting. Good light in cowsheds is of particular importance in connection with milking operations, and as far as possible the light should be concentrated on the hindquarters of the cows. For those reasons, the most desirable method of natural lighting, especially in double-range, tail-to-tail cow houses, is from overhead. The disadvantages, such as "scorching" of the animals, sometimes associated with roof or ridge lights directly exposed to the sun's rays may be eliminated by arranging cowsheds or other animal buildings so that the overhead lighting comes only from roof lights on the side facing north or east, thereby eliminating or reducing the heating effects from the sun's rays within the building.

Overhead lighting can be provided by fixed roof lights evenly spaced in the roof-slope or, as already mentioned in connection with outlet ventilators, by a system of combined lighting and ventilation in the ridge.

—V.H. 12

zero reading in A , leave it like this for two or three minutes If there is no leakage past T_1 the mercury level in A will not fall

9   Turn T_1 through a clockwise, one-eighth turn   Air rushes into A   squeeze the rubber tube connecting A and C so that the inrush is slowed down and the mercury column in the graduated capillary of A is not broken up   By means of the pinion adjust C until the mercury is at the zero mark in A

10   Shut off the air and connect A with D by an anti-clockwise quarter turn of T_1

11   *Five or six times raise C by hand so that the mercury level in it is not above the top of A (or mercury will be driven over into D) nor below the zero mark on A (or potash may be sucked over into A)*

12   Turn T_2 through a one-eighth clockwise turn to connect with the absorption system

13   Adjust C and I so that the potash in E and H is at the former levels L_1 and L_2

14   By a one-eighth clockwise turn of T_1 shut off A and read the mercury level in its graduated capillary

15   Turn T_2 one-eighth anti-clockwise

16   Turn T_1 one-eighth anti-clockwise and repeat operations 11 to 14 inclusive   If the same reading is observed in the graduated capillary as before, this may be taken as the CO_2 content of the air sample

17   If anomalous results are obtained, examine T_1 and T_2 to make sure they are not blocked by grease, or replace the potash solution by a fresh sample   When the apparatus is not in use, I should be stoppered

CALCULATION OF AIR VELOCITY (AIR FLOW)   The calculation of air flow is made as follows —

Let a = air supply per head per hour (cub ft.)

x = CO_2 production per animal per hour (cub ft.) (for values of x see page 135)

k = concentration of CO_2 in parts per 10 000

Now if the amount of CO_2 in fresh air is taken as 4 parts per 10 000 the concentration of CO_2 in the building will, for practical purposes, be represented by the formula —

$$k = 4 + \frac{10\,000\,x}{a}$$

Example   Calculate the number of air changes per hour taking place in a dairy cowshed from the following data —

Cowshed dimensions   45 ft. × 32 ft. × 14 ft.
(14 ft. being the average not the actual height)

No of animals in building = 20 Shorthorn cows

CO_2 content of air in building, estimated by Haldane's apparatus = 16 7 parts per 10 000

(i) The *total* cubic air space of the building $= 45 \times 32 \times 14 = 20,160$ cub. ft.

The *effective* cubic air space of an occupied building = total cubic air space less space occupied by bodies of the animals.

$= 20,160 - (25 \times 20)$.

[25 cub. ft. is space occupied by cows of larger dairy breeds.]

$= 20,160 - 500$.

$= 19,660$ cub. ft.
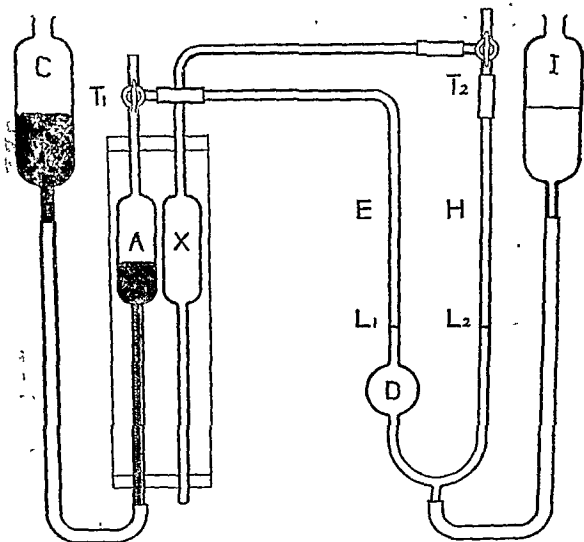
FIG 49—Diagrammatic representation of the above

(ii) Using the formula

$$k = 4 + \frac{10,000x}{a}, \text{ where } x \text{ is 5.8 cub. ft. of } CO_2 \text{ per hour}$$

we get $16.7 = 4 + \dfrac{10,000 + 5.8}{a}$

i.e., a (or fresh air supply per head per hour)$= \dfrac{58,000}{12.7} = 4567$ cub. ft.

∴ Total fresh air supply to building with 20 cows $= 4567 \times 20$ cub. ft.

(iii) No. of air changes per hour$= \dfrac{\text{total fresh air supply to building}}{\text{effective cub. air space of building}}$

$$= \frac{4567 \times 20}{19,660} = 4.6 \text{ (approx.)}$$

Wall lighting is less efficient than overhead lighting, and in a double range, tail to-tail cowshed some difficulty may be encountered in securing adequate illumination where it is most needed, i e at the hindquarters of the cows, when the former is the only means of admitting light to the building Windows should preferably face north or east, so that strong sunlight does not fall directly on the animals The best form of window for all types of animal habitation is undoubtedly the adjustable hopper type, which provides both light and ingress of fresh air Windows with metal frames have a higher initial cost than those with wooden frames, but are cheaper in maintenance

The following are the minimum areas of glass recommended for animal habitations —

Cowsheds 4 sq ft of roof lighting per cow, rather more than this area for wall lighting.

Calf Houses Hopper type window, 4 ft × 3 ft for each three single pens and *pro rata* for larger pens In addition roof lighting at the rate of 50-60 sq in per calf is desirable

Stables At least 4 sq ft of glass for roof lights, or 12 sq ft for windows for each pair of horses

Piggeries Roof lighting at the rate of 50 sq in per pig, or windows—1 sq ft per pig, a window being placed opposite each pen

Loose Boxes At least 4 sq ft of glass for rooflights or 12 sq ft for windows, should be allowed for each box

Poultry Houses At least 0 5 sq ft per bird

Artificial Lighting The requirements of good artificial lighting include (a) adequacy , (b) constancy and uniformity i e , absence of flicker, over the necessary area of work (c) prevention of glare, and (d) avoidance of shadows on the work

For animal habitations, electric light is undoubtedly the best form of artificial illumination It is clean, adds no products of combustion to the atmosphere, is easily led to any point requiring illumination and, if properly installed, is relatively free from any danger of causing fire Electricity in farm buildings has recently been investigated by a Study Panel of the Electrical installations Committee appointed by the Minister of Works and this Panel makes the following recommendation* ' Electric lighting can of itself greatly improve working conditions and cleanliness, in farm buildings and care should be taken in planning the wiring of both

new and existing premises that adequate lighting provision is made in the buildings and where necessary in the farmyard approaches. The number and size of lamps should be arranged to provide good illumination over all working areas; for example, in a single-range cowshed for twelve cows, two lights on the wall along the feeding-passage and at least three lights on the wall behind the cows are advisable. Bulkhead type fittings to take 60 or 100 watt lamps are suitable for wall mounting, and should be of waterproof pattern in cowsheds and dairies." In a double-range building lights should be suspended over the central gangway, fluorescent lighting in this position is very effective. It is also a great advantage in all types of animal house if portable lights, and plugs for these, are placed at suitable places within the building. These greatly facilitate veterinary operations such as the taking of blood samples, tuberculin testing, calving, etc. It must be emphasised that cheap electrical installations are liable to be dangerous; farm electrification should only be undertaken by firms which specialise in this type of work.

Coal-gas lighting gives excellent results so far as illumination is concerned, but since it warms the air and gives rise to undesirable by-products resulting from combustion, it is less satisfactory than electricity as a means of lighting animal habitations. The risk of fire is also greatly increased.

If neither electricity nor coal-gas is available, acetylene gas, petrol gas or paraffin-oil lamps will have to be used. It is still the practice in many rural areas for milking and other cowshed operations to be carried out by means of light provided by the old-fashioned hurricane lamp. The light emitted by these lamps must be regarded as unsatisfactory for the purposes of clean milk production. The paraffin-vapour type of lamp provides a more suitable means of illumination; such lamps are reasonably safe, economical, and give a brilliant light which is adequate for all purposes.

SECTION IV

THE HOUSING OF ANIMALS

This section forms a general introduction to the layout, design and construction of buildings, in so far as an understanding of these subjects is necessary for the inspection of, and reporting upon, animal habitations. Work of this nature demands a general knowledge of building materials and their application in the construction of agricultural and other buildings for housing livestock, as well as the ability to interpret and criticise plans and drawings of existing or proposed new buildings. Unessential details have as far as possible been omitted, but the information given should help the reader to acquire the knowledge required to prepare sketch plans and to make reports, and also to offer suggestions for the improvement of such buildings when this is deemed necessary.

GENERAL PRINCIPLES AFFECTING THE DESIGN AND CONSTRUCTION OF BUILDINGS FOR HOUSING LIVESTOCK

Farm buildings may be divided into two general classes, *viz.*: those for the housing of livestock and those for the storage of feeding-stuffs, implements, etc. The former should be reasonably warm in winter and not subject to overheating in summer. They should never be liable to undergo sudden changes in temperature and should, therefore, be constructed from materials which will function as insulation between outdoor and indoor temperature levels. The maintenance of an even temperature is less important in buildings used for storage, but such buildings must be dry and weatherproof. It is desirable, too, that storage buildings should be soundly constructed so that they may be adapted, if necessary, for the housing of livestock.

It is impossible to design an ideal set of buildings which would be equally suitable for livestock farming all over the country owing to the differing methods of animal husbandry and farm management which in turn are governed by climatic, geographic and other conditions such as the size of the farm, the economic value of the land and intensity of its use, and the design, condition and layout of existing buildings. No matter where the buildings are situated, however, the design should only be decided upon after full consideration of the

requirements for establishing and maintaining good health, for preventing the spread of disease, for securing cleanliness, adequate light, ventilation and for obtaining economic working conditions.

Generally speaking, it is undesirable and unsatisfactory to attempt to design buildings capable of being used by more than one kind of stock, but an exception to this is the provision of loose-boxes which can conveniently be used for the housing of almost any livestock and which are consequently an asset to any farm.

Selection of Site. Given freedom of choice the buildings should be on dry ground of a moderate altitude, have a southern aspect, and be sheltered from the prevailing cold winds. They should be situated so as to have easy access to, but set back from, a main road, and be served
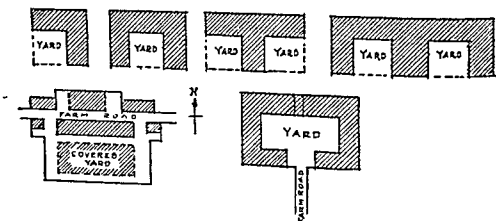
FIG. 50.—Various arrangements for Farm Buildings.

with a plentiful supply of good water and also, if possible, with electricity. Buildings situated near the centre of the farm land are usually more convenient than if placed otherwise.

The site should, if possible, have a well drained sub-soil; a compact gravel or chalk is preferable to a damp clay or loose sand. The site should also allow of easy disposal of farm drainage and surface water.

Any difficulty experienced in selecting a sheltered site may sometimes be overcome by erecting barns, granaries and similar storage buildings to the windward side, thus forming a protection for the buildings housing livestock.

In, or very near to, towns the choice of site is usually limited, and consequently greater care in its selection is called for; amongst sites which should be avoided are low-lying and damp land, such as riverside, reclaimed or made-up ground, and situations adjoining canals.

Arrangement of the Buildings on the Site. Almost always, the arrangement of the various buildings comprising a farm steading will,

in the first instance, be ruled by (a) the proximity of roads, and (b) the configuration of the ground.

The rules for planning may be briefly stated as follows :—

(1) The farm buildings should be kept well away from the farm-house and workers' cottages, but consideration must be given to the distances being not *too* great, otherwise stockmen or other animal attendants might be reluctant to turn out at night or in bad weather to give the animals the required attention.

The farmhouse should never be placed to the leeward side of the steading or farm buildings, in relation to the prevailing winds. Attention to this point tends to prevent flies and smells from the manure heap being blown towards the dwelling-house.

(2) The arrangement of a group of buildings should be such as will admit of the free passage of sunlight and air, and yet ensure economy of labour in the tending and feeding of animals. This latter requirement is greatly facilitated by ensuring that both the farm and the buildings themselves are served by a well-surfaced road, the surface being extended into the yards.

The buildings may be arranged in the shape of the letters "L," "U", "T" or "E", with a road round the outside; the open end of the letters facing South ; or they may be arranged around a rectangular court or yard at the end of the farm road (see Fig. 50) or in parallel lines on each side of it. An outstandingly bad feature of most farms is that the buildings have been added to from time to time on no definite plan, and as occasion seemed to demand, with the result in many cases of a hopeless muddle which involves labour out of all proportion to the capacity of the farm.

(3) The court formed by a group of farm buildings, in any of which buildings animals are housed, should be so proportioned that the least dimension of the court's surface shall be not less than twice the height above the ground of the ridge of the highest building forming the group. From this it should not be assumed that all farm buildings ought to be grouped to form a courtyard, but there is no objection to a quadrangle if the area is great enough to give plenty of ventilation. The rule given above would work out at a quadrangle measuring 36 feet in its least dimension if the highest building measures 18 feet from the ground to the ridge.

An example of a farm steading embodying some excellent principles is shown on the plan in Fig. 51. This plan should be carefully studied, as it incorporates some of the points considered desirable for a modern dairy farm which, with certain adjustments, might be used

FIG. 51.—A good arrangement of farm buildings.

fcr other forms of husbandry. It will be seen that the buildings are arranged in parallel lines on each side of the main farm road from the highway, which divides on reaching the farmstead. The first branch serves the buildings used for the storage of implements, etc., and also the stable for horses. It should be noted that the isolation boxes are situated at one corner on this side, well away from all other stock. The second branch road serves the main group of livestock buildings, which include the cowhouse with dairy attached and a partially covered yard which is separated from the former by a calf-rearing unit and a range of loose boxes.

GENERAL CONSTRUCTION
BUILDING MATERIALS

The following notes on building materials are confined to those in general use for ordinary farm buildings. There is, in addition, a great variety of proprietary articles, many of which are good and useful, but which, owing to their cost, are out of the question for most agricultural buildings.

Bricks. Brickwork is probably the most widely used of all the materials utilised for building construction. Bricks are made either of a natural clay or a suitable brick earth. To the former must be added any of the necessary ingredients in which it is deficient. All clays and brick earths vary in character.

Natural plastic clays are composed of silica and alumina, and contain a very small proportion of lime, magnesia, sodium and other salts. They tend to shrink if used alone, but attain great hardness when burned.

Brick Earth or loam consists of clay (*i.e.*, silicate of alumina) and sand. The latter prevents shrinkage and cracking, but reduces the hardness of the resultant brick. Most loams require the addition of lime as a flux, in order that the materials may be bound together. Marls or calcareous clays contain a large proportion of chalk. Suitable brick earths, whether natural or artificial, should contain such proportions of carbonate of lime and oxide of iron, etc., as will form a sufficient flux to fuse the constituents when in the furnace, but an excessive quantity will cause them to run together, and result in an over-burned and badly-shaped brick. The oxide of iron in a brick helps to bind the brick, and gives it its colour, whilst the carbonate of lime is purely a binding material.

Bricks should be of regular and uniform size, shape, texture and colour, and well burnt. They should be free from cracks and flaws, sharp on the arrises, and give out a clear ringing sound when struck with a hard material. It being impossible to receive delivery of all bricks in this perfect condition, those slightly damaged are quite good for building in concealed positions, provided that the brick is hard and well-burned. Moderately rough, irregular and chipped bricks need not be objected to for partitions or walls which have subsequently to be plastered or covered in any way. Porous bricks should never be used in foundations or in external walls. They will absorb water, and are likely to weather badly. It is economical to build

the brickwork of agricultural buildings in cement and lime mortar, as it results in much more durable and water resisting work, reducing depreciation and giving a stronger result than lime mortar alone

Ordinary Building Bricks Ordinary building bricks vary slightly in size* according to the brickworks or district in which they are made They may be hand-made or machine-made, but in either case are moulded Hand-made bricks are usually wire-cut, and have no frog or depression, which results in a heavier brick and one which does not bond so well owing to the absence of the frog. Machine-moulded bricks are usually more regular, have a frog on one or both beds, and usually bear the name of the brickworks at which they are made Ordinary clay bricks are obtainable in various shapes for special purposes *Bullnose bricks* are used for forming rounded corners at doors, windows, piers, corbels, window sills and other projecting parts which, if built with a sharp arris (edge), might injure animals *Splayed bricks* are used for intakes, sills, window openings and corbelling.

Facing bricks are special bricks made in a variety of kinds for use with ordinary brickwork to give walls a durable and sanitary finish.

Enamelled Bricks —Enamelled bricks refer strictly to those finished on one or more surfaces with coloured or white enamel, but the term is often loosely applied to cover enamelled, glazed and salt-glazed bricks, which are three totally different products

Enamelled fireclay goods of any description, whether bricks, tiles or sanitary fittings, are easily distinguished by reason of their opaque enamel, which does not depend in any way upon the body of the brick for its colour Before firing, the surfaces are first dipped in the enamel solution, passed into the kiln, and fired.

Salt-Glazed —Salt-glazed bricks are ordinary fireclay bricks which have had common salt thrown upon their surface while they are in the kiln This causes the brick face to flux, and results in a light or dark brown glaze These bricks are the cheapest form of impervious facing brick, and should be used on the lower parts of the walls of all animal habitations They present a sanitary surface which may be washed with ease

Blue Bricks —Most blue bricks are made in Staffordshire from clay which contains from 7 to 10 per cent of oxide of iron and are burned in the kiln at a high temperature They are the hardest and most durable of all bricks and are recognisable by their deep blue-black colour and smooth metal like face They are useful for the jambs of gate ways stable doors, dadoes of courtyards and other situations likely to receive rough usage

Staffordshire blue bricks specially made for paving stables are practically non-porous, extremely hard and very durable, but, unfortunately, they are slippery. To overcome this they are usually grooved during manufacture , the grooving, however, gives rise to another fault, *viz* , a lodgment for dirt and moisture When these bricks are used the groove should be not less than $\frac{3}{4}$ inch wide, not more than $\frac{1}{4}$ inch deep, and should run with the long axis of the brick

Dutch Clinkers —Dutch clinkers are only used for paving or flooring. They are small, very hard, well burned bricks, and vitrified throughout; their colour is bright buff, although the addition of oxide of iron will yield a black pavement brick. They are chamfered on the edges, thus forming a grooved floor to resist slipping

*See British Standard Specification No 657
"Dimensions of Common Building Bricks"

Perforated Bricks—Perforated bricks are ordinary building bricks made with a number of perforations running from bed to bed. They are frequently used in in the south of England and London for lightening the work, but are rarely used in Scotland

Hard-pressed *ventilating bricks*, or *air bricks*, of various patterns are often used instead of gratings. (See Ventilation.)

Tiles. Ordinary roofing tiles, usually red in colour, are made from a good plastic clay. Flat plain tiles are used for all classes of work, and are made in a great variety of qualities. Tiles should not be laid at a flatter pitch than 45 degrees

Pantiles, commonly used on sheds, byres and other buildings are rough and heavy, and do not keep out the wind unless torched on the underside. They are popular in some districts, as they can be laid on roofs with a pitch as flat as 25 degrees, and are easy to fix. *Glass Pantiles* are obtainable for insertion in pantiled roofs. They can be easily inserted in an existing pantile roof

Building Stones. Stones used for building purposes may be divided geologically into two classes, viz., those derived from the igneous rocks and those from the sedimentary rocks. To the former class belong granite, whinstone, trap-stone, etc., and to the latter class sandstone and limestone

Granite varies greatly in composition and colour. The best British granites come from Aberdeenshire, Guernsey, Devon, Cornwall, Westmorland, and Wicklow in Ireland. It is sometimes used for street paving setts, but is apt to become slippery. For farm building purposes probably the only use to which granite can be put is for paving stable-yards in the form of setts, and for steps and thresholds

Whinstone is a close-grained dark blue or black stone with no definite bed or or line of cleavage. It is used principally for road metal, the aggregate of concrete floors, and for paving setts, being superior in many respects to granite for the latter purpose. It is not recommended for building, as it is inclined to draw damp and sweat on the surface

Sandstone consists of quartz in the form of sand, held together by the carbonates of calcium and of magnesia, the oxide of iron and silica, etc. Sandstone is most in demand for rubble building and hewn work, owing to its regularity of texture and workability. The durability of the sandstone depends upon the power of the binding material, and its ability to resist weather. The sand or quartz is, of itself, indestructible. The hardest varieties of sandstones are much used for paving, copings, steps, foundation blocks, etc

Limestone is calcium carbonate in combination with iron, silicon, magnesium, etc. Well known examples of limestones are (1) Portland Stone obtained from the Upper Oolite series of sedimentary rocks in the island of Portland, and (2) Kentish Rag stone which is compact, of a bluish tint, and is chiefly used for rubble building, paving setts, road metal, etc., (3) Bath stone varying in colour from white to creamy yellow, and when first quarried, soft and moist. It may be cut out by a saw, and is easily worked for fine carving, but after exposure to the atmosphere it hardens and becomes very durable

Slates. The chief varieties of slates are Welsh slates, which have a good cleavage and may be split into very thin metal, and Westmorland slates, which are hard, tough and very durable, and obtainable in a variety of pleasing colours Scottish slates are usually very durable, but are thick and heavy

A good slate should give out a sharp ring when struck. It should stand trimming and holing without fracturing. Slates may be tested by weighing them before and after twenty four hours' immersion in water A slate, set on edge in water to half its height should not absorb water in the upper and unsubmerged part. In a really good slate no sign of moisture will be seen above the water line

Thick slabs of slate are sometimes used to form cisterns and other containers for water Such cisterns are not to be recommended, as the liability of the joints to leak makes them unhygienic and unreliable

Limes, Mortars and Cements. Lime for building purposes, such as making mortar and plaster, is obtained by heating limestone, limestone chalk, shells or any substance composed of calcium carbonate The limestone is burned in a kiln, along with fuel, in order that the carbonic acid gas and any moisture may be driven off and escape into the open air

For the preparation of ordinary building mortar without the use of a mortar mill, one part of lime shells is placed on the ground or on a cement floor and surrounded by about three parts sand, and the whole made thoroughly wet The quicklime immediately absorbs the moisture and begins to slake by effervescing violently, giving out heat and falling into a fine powder By this process the caustic properties of the quicklime have been lost, and the substance is converted into hydrate of lime (slaked lime) By mixing this with the sand, and adding a sufficient quantity of water, lime mortar for building purposes is produced. Pure slaked lime has little strength as a mortar without the addition of sand The proportion of sand to lime, in preparing mortar, depends entirely upon the characteristics of the slaked lime and of the sand used As pure slaked lime hardens on the surface by absorbing CO_2 from the air, the unexposed parts of the mortar will remain soft and unsuitable as a mortar The addition of sand permits the entry of the air, and enables the mortar to set into the form of a cement with binding qualities

In preparing lime for internal plasterwork, lime shells are slaked in an "ark," which is any form of enclosure or tank which will hold the quantity to be slaked Sometimes an "ark" is formed in a plasterer's yard by enclosing a corner with sand, filling in the lime shells and applying water in sufficient quantity to reduce the shells to an inert and saturated condition to ensure thorough slaking and prevent blisters and "blows" in the finished plasterwork. After being thoroughly cooled, the sand in required proportion is mixed with the lime and the whole left for from 4 to 6 weeks to weather before use Ox or goat hair, or manilla fibre, in the proportion of one pound of hair to every two cubic feet of "coarse stuff," should be mixed with the plaster lime in order to bind the material into position in the building.

Portland Cement.—Portland cement is probably the most important of all building materials being used for foundations, floors, paving, building purposes and an endless variety of structural works It derives its name from a supposed similarity in appearance to Portland stone Chalk and clay are the components of Portland cement * They are mixed together by the "wet" process The proportions of chalk and clay used depend entirely upon the composition of the chalk

*See British Standard Specification No 12 "Ordinary Portland and Rapid-Hardening Portland Cement."

before it is burned   It is necessary to obtain a mixture containing from 25 to 30 per cent of clay. The method followed is to mix the chalk and clay in water till it attains the consistency of a creamy liquid known as "slurry"   This is allowed to settle in large tanks or reservoirs for several weeks   When the deposit becomes nearly solid, the liquid is run off and the solid dug out, dried over coking ovens, burned in kilns at a high temperature, and afterwards ground to a fine powder. The strength of the cement depends largely upon the fineness of the grinding London Portland cement, which is in world-wide demand, is made principally on the Thames and Medway   The colour varies from a bluish-grey to a light-brown   Portland cement will draw damp and moisture, which, in a comparatively short time, will cause it to set in the sack   If required for home use it should not be obtained in amounts which would involve its being stored for more than 8 weeks ; it should always be kept in a dry store

Cement Mortar —Cement mortar for building purposes is composed of about three parts clean sharp pit sand, or river sand, and one part Portland cement, mixed with clean water free from organic matter or other impurities   It must be used fresh as it sets rapidly   Mortar left over at the end of one day must not be mixed with fresh material the next day

Cement Concrete for the foundations of walls, retaining and other walls, etc , is composed of a clean graded aggregate, consisting of clean broken stones, bricks or large gravel, clean graded sand and Portland cement mixed with clean water The proportions of foregoing vary with the nature of the work and the class of aggregate and quality of cement used   For ordinary foundations the following is recommended —

Stones or bricks broken to pass a 2-inch ring	4 parts
Clean sharp sand	2 parts
Portland cement	1 part
Water in sufficient quantity	

The material should be mixed on a platform of close boarding or stone, or cement pavement (not on soil), turned over twice dry and once after being wet, immediately thereafter being turned into the foundation trenches

Cement Plaster, consisting of clean, sharp sand and Portland cement mixed in three or four to one proportions, is used in rendering or plastering the inner or outer surfaces of walls, partitions, cow byres, divisions, piggery partitions, etc   Care should be taken to avoid using a plaster too rich in cement, otherwise hair-cracks or crazes will develop   A sand-faced finish is preferable to a polished one in this respect, but it is nevertheless more difficult to clean, as in the case of a sick loose-box   Cement plaster lends itself to the introduction of rounded corners and angles, and to a hygienic finish adjoining metal fittings in stables

Rough-Casting for the outer face of walls consists of cement plaster finished on the surface with pebble or crushed stone dashing

Reinforced Concrete consists of fine concrete strengthened with iron or steel rods or expanded steel sheets, so placed that the reinforcement will take up the tensile strains set up in the concrete   It is now extensively used for the formation of stanchions, posts, beams, partitions, load bearing and retaining walls, tanks, stall divisions, upper floors, etc

Asphalts. True mineral rock asphalt is used in different forms for paving road ways, covering platform roofs, and lining the walls of basements to exclude damp (often called "tanking")

Mineral rock asphalt is a natural limestone impregnated with natural bitumen. This rock is found principally in the Val de Travers (Switzerland), Seyssel and Montrottier (France), and Limmer (Hanover) Mineral rock asphalt may be laid in two ways, viz, "powder work" and "mastic-work "

Powder-Work is used for roadways. The material is prepared by grinding the rock to a fine powder, which is then roasted in a special plant, conveyed hot in steel waggons to the work, and spread on a solid concrete foundation The powder is immediately beaten into position with hot iron rammers, and finished to a uniform surface The constant traffic of a busy thoroughfare soon renders this form of roadway very hard and durable

Mastic-Work is used for roadways, pavements, roofs, and as a lining for the walls of basements to exclude damp The mineral rock asphalt is prepared by grinding and mixing with pure Trinidad bitumen and other ingredients, after which it is moulded into blocks and stamped with the manufacturer s name. At the site of use, these blocks are melted in metal pots, and "cooked" to the proper consistency, a certain amount of pure bitumen and fine washed grits being added This work is spread in two layers, for horizontal work the joints being lapped The material is spread with the aid of a wooden float. Being tough, it requires energy and kneading into position to exclude all air or gas bells which if left in, would result in blisters. Mastic-work should never be executed in damp or wet weather

Felts and Bituminous Roof Coverings.

A variety of *haired felts* and *fibre felts* are obtainable in rolls for building purposes For covering roof boarding, before the slating of the roofs is applied, the cheapest form of felt is suitable These felts consist of a thin mat of vegetable fibre, impregnated with a solution of bitumen A higher-grade material is manufactured, consisting of haired felt s milarly treated with a coal tar oil or bituminous solution. These haired felts are suitable for deafening floors by being nailed to the top or botom of the joists before the application of the flooring or ceiling These are suitable for temporary or unimportant structures, where appearance is a matter of little importance They may be rapidly and easily fixed by unskilled labour

Timber for Building Purposes.

The study of timber, its growth, cutting, conversion, seasoning and characteristics, is a wide subject demanding long application and experience Timber for building purposes is usually procurable ready cut in the usual commercial sizes

Characteristics of Good Timber.

Timber of good quality should be straight in the grain, free from large, or dead, or loose knots, shakes and waney edges It should be thoroughly seasoned, uniform in colour, and as free from sap-wood as possible

Timber, when cut with a saw, should give out a fresh smell, should cut freely without clogging, and present a clear and firm surface, free from any dull or spongy appearance A spongy appearance should lead one to suspect dead timber, that is, timber cut from a tree which had died before being felled

In selecting timber it should be remembered that closely-set, dark-coloured annual rings indicate strength, whilst wide-set annual rings, and rings of a light colour, indicate the newer or sapwood. Good timber, when struck, should give out a clear, ringing sound

The Commoner Defects in Timber.

The defects which should be looked for in timber are various. These defects are natural, and common to all kinds of timber. In many classes of work a certain percentage of such defects as are mentioned here-

after is permissible, it being impossible to get perfect timber except at a very great cost

Sapwood—Of the defects in timber, the most serious is the presence of an undue proportion of sapwood This is due to the felling of immature trees The sapwood is spongy in grain, showing large annual rings, and is generally of a bluish colour The sapwood in a board can be distinguished from the heartwood by difference in colour Sapwood is very liable to decay, and is particularly subject to attack by "dry rot" Being immature it lacks strength in comparison with heartwood, and is therefore unsuitable for structural work

Shakes—Shakes in timber are cracks, faults due to uneven contraction in the seasoning or drying of the timber

Knots—Knots in timber are the cross section of branches and shoots These are particularly numerous in red pine or redwood, less numerous in white pine, and of rare occurrence in good American yellow pine Timber containing large loose knots should not be used for structural work, but firm, undecayed knots, if not excessive in number or too large, are not objectionable

Waney Edges—"Waney edges" is a term which refers to a batten or "deal" having a splayed or rather slightly rounded corner or edge This at once reveals the fact that the particular scantling has been derived from the outer part of the tree, and is therefore almost entirely composed of the newest of the sapwood, or has been derived from a small and, therefore, immature tree Such timbers may be used for rough or unimportant work if placed in an airy position

"Dry Rot" in Timber—From the time a tree is felled, the timber becomes liable to attack by "dry rot,"* but the disease is usually most active when the timber is in position in a structure

This disease, which is due to several related fungi, especially *Merulius lacrymans*, thrives most readily in situations which are unventilated and have a warm, damp atmosphere The spores of the fungus may get into the timber before it is built into position, or they may be carried by wind, on carpenters' tools, or spread to sound timber from the temporary or permanent proximity of old infected timber

A common situation in which "dry rot" is found is under ground floors, where the joisting and flooring boards are attacked, particularly if the site of the building has not been cleared of vegetable matter and properly covered with surface concrete It is, therefore, necessary to provide thorough air circulation to the spaces under all such floors by inserting air-bricks in the walls so as to give through draught

Unventilated spaces in roofs, enclosed by timber are also likely sites for the occurrence of "dry rot," since in event of a leakage and the presence of infected timber the spores will rapidly germinate and grow, ultimately reducing the timber to a powder

The appearance of the fungus varies with the situation, stage of growth, and the conditions promoting its growth Sapwood, particularly in white pine, is very liable to attack Experienced observers can often detect the presence of "dry rot" in a structure by the characteristic musty odour emitted by the fungus, and the "atmosphere" which it creates

The fungus, under suitable conditions, grows and spreads rapidly, in the early stages having an appearance somewhat like frost, and later developing

*The term "wet rot" is applied to decay started in the standing tree, "dry rot" to "the form of decay induced in timber that is apparently sound when first used as constructional material"

into a mushroom like skin spread over the surface of the timber. The fungus may spread over, and into, the joints of brickwork, plaster, masonry, etc., in search of moisture, but it derives nourishment only from the woodwork.

Almost without exception, soft, unseasoned sapwood sooner or later becomes attacked by the fungus. Highly resinous woods, e.g. larch appear to be less liable to attack than such practically non resinous woods as white pine.

It may be taken that there is no cure for dry rot in timber once it is attacked. The only safe procedure is to cut out all affected parts together with the parts adjoining. These should be carefully removed from the building without allowing any of the dust or spores to be blown about, and disposed of by burning.

Replacement of woodwork should be carried out with perfectly sound and well-seasoned timber, the surfaces of which have been coated with creosote oil, after having scorched the surfaces of all walls and existing woodwork in the vicinity with a blow lamp. Immediately after the application of the blow lamp, an additional precaution is to coat the surrounding woodwork with a 1 to 2 per cent solution of corrosive sublimate. Great care must be taken in the use of this solution, because of its highly poisonous character. A safer, but less effective method, is to use a solution of copper sulphate.

WALL CONSTRUCTION

The walls of a building should be looked upon primarily as a shelter from cold wind and rain. A secondary duty is to support the roof and any upper floor, as well as to form a support for stall divisions and stable or byre fittings, etc.

It is obvious that a wall must not readily absorb moisture either from driving rain or by capillary attraction from the soil. The preliminary to building a wall of any description is to excavate a foundation trench of the depth necessary to remove all top soil and humus, down to a bed of firm clay, sand, gravel, or rock. The formation should be levelled or stepped into level stretches. For concrete foundations the trench should be of the exact width of the concrete. The thickness and width of a foundation will depend upon the nature of the soil, but it is a good rule to make the thickness never less than 9 inches, and preferably 12 inches thick for the usual farm building. The width of a foundation may be from 9 inches to 12 inches more on each side than the thickness of the wall to give the necessary bearing area upon the soil. If concrete foundations are not used, which is rarely the case to-day, a foundation may be constructed in brickwork by forming projections called footings. There are a stepped increase in the thickness of the wall, greatest at the base. They are open to objection, as being full of joints they give more readily than concrete to any soft part of the soil and cause a settlement in the building. Brick footings tend to draw moisture from the soil. Concrete foundations are always to be recommended as they are monolithic, resist the passage of moisture and are strong. Sometimes brick footings are built on a concrete foundation as shown in Figure 57.

Upon the foundation, the top of which should be level, the wall is built and brought up all round the structure to a level surface to receive the damp-proof course about 4 inches above the ground level. In this case the stable or byre floor would be 2 inches above the damp-proof course, making the floor 6 inches above the ground if the site is level. The damp-proof course is important and must be executed with care. For details of construction refer to the section "Dampness in Buildings and its Prevention."

Brickwork.—Generally speaking, brickwork in the form of 9-inch solid load-bearing walls, strengthened by such piers as may be necessary under building by-laws, will meet all requirements for farm buildings. Where piers are needed they should be placed on the exterior of the buildings, but, whenever possible, piers and unnecessary breaks and projections in wall surfaces should be avoided. Reinforcement of brickwork may sometimes render piers unnecessary, but expert advice must be sought in each case.

Where farm buildings are to be erected in very exposed positions, or where the bricks used are unusually porous, it may be desirable to construct walls on the cavity system. External rendering is another valuable means of increasing the weather-resisting qualities of walling. Portland cement, lime and sand, with or without the addition of pebbles to the mixture, and the many cement finishes now on the market are suitable for this purpose.

In framed structures, brickwork used for filling in the panels should be bonded into the steel stanchions or concrete piers.

Stone of various kinds is an excellent material for the walls of farm buildings in districts where it is readily available and builders are familiar with its use.

Concrete.—Apart from its usual uses in foundations, solid walls, lintels, etc., concrete is now available in the form of many types of precast blocks—solid, hollow, vibrated or cellular. These may be used for load-carrying walls and their thermal insulation value is about equal to brickwork of the same thickness. Cellular concrete blocks have higher thermal insulating qualities than the other types mentioned. They may be used as the inner lining of cavity walls in conjunction with brickwork for panel filling, in framed construction or ordinary walling. Cellular and lightweight concrete are important recent developments, but so far have been little used for farm buildings.

Sheeting.—Various forms of sheeting are available for use in framed structures. Most of them are obtainable in a wide range of standard sizes and colours, and are easy to cut, but they suffer from the disadvantage that they are likely to be damaged on impact, and for this reason when used for walls should not be taken down to the

floor level, but built above a solid base or plinth at least 4 feet 6 inches high. There are three main types :—(a) Those for internal use, such as wall boards of the less dense kinds, plaster board or asbestos-cement which may be used for ceilings, and certain plywoods. (b) Those for external use, such as flat, corrugated, or channelled asbestos cement, corrugated iron (galvanized, painted or both), protected metals, certain types of resin bonded plywoods or wall boards, weather boarding, tiling or slating. (c) Combinations of (a) and (b), such as tiles or slates with an internal lining, or double or treble asbestos-cement sheeting. These provide both external and internal faces and some thermal insulation resulting from the air space between the components.

Internal finishes to walls.—A smooth and unbroken surface is necessary in buildings such as the cowhouse and dairy, and other stock buildings ; it is also desirable in food and grain storage buildings where cracks and crevices may harbour insects and other pests. In most cases brickwork, especially that constructed of enamelled bricks, or concrete jointed to a regular face and colour washed, is suitable, while the addition of a smooth impervious rendered dado, to a height of 4 ft 6in and coved at the floor, provides a clean finish to walls of buildings housing livestock.

ROOF CONSTRUCTION

The section on "Air and Ventilation" emphasises the importance of the open roof for animal habitations. It is particularly important that the roof trusses should form the least obstruction to air and light, and that, if possible, they present the smallest of surfaces for the lodgment of dust. On this account, steel trusses are always preferable to those composed of wood.

Roofs composed of steel trusses, wood or steel purlins and boarding, covered with felt and slates or tiles, possess all the qualities desirable for animal habitations. This form of construction is warm in winter and cool in summer. The covering is durable and easily repaired. The same type of roof with wood trusses comes next in favour. A roof of similar construction, but lighter in its members, covered with one or two thicknesses of bituminised felt or canvas fixed properly to the boarding, is permissible where slates are not available. If cost is a serious consideration, a very much lighter structure of the same type, but covered with corrugated iron, may be used. This covering will dispense with the costly boarding, but it must be borne in mind that it makes the building cold in winter and hot in summer. This, however, may be overcome by using asbestos sheeting. Corrugated iron roofing is suitable for open cattle courts, manure pits, cart sheds, etc.

Asbestos cement roof-covering is manufactured in corrugated sheets for fixing direct to purlins, and in flat "slates' for fixing to battens or to roof boarding. The advantages of asbestos cement roofing are that it is non-corrosive, comparatively light, insulating and requires little attention.

Another form of roof-covering is asbestos protected metal. This consists of corrugated iron sheeting, covered on both sides and on all edges with asbestos fabric, and having a bituminised finish. It is very lasting, and involves practically no maintenance costs.

It must be appreciated that, while sheeting requires the support of trusses and purlins only, tiles and slates require a heavier supporting structure including rafters and battens, and an internal lining may be necessary in buildings erected for the housing of livestock and for the dairy.

FLOOR CONSTRUCTION

The essential requirements for a hygienic floor are that it be non-porous, capable of being easily cleaned and quick drying ; it must be non-slippery, durable, hard-wearing, free from damp and be comfortable for the animals. Since the majority of animals are kept for profit and not for pleasure, the question of expense has also to be considered. A floor that does not soak in water and which readily dries after it has been flushed lasts longer than one that retains moisture.

Owing to the fact that animals void their faeces and urine where they stand it is necessary that the floor be composed of some material that will not absorb moisture, otherwise the flooring and the subsoil would become permeated with urine, etc., and be constantly damp and cold, and the air of the building would be vitiated with the products of decomposition which, if not actually causing disease, would at least tend to lower the vitality of the animals and render them more susceptible to disease. Damp floors and damp walls are marked predisposing causes of illness and general debility.

Slippery floors have been responsible for many accidents to animals, especially to horses and cattle. The more impervious a floor is to moisture, the harder and denser is its structure, but unfortunately the surface of such a floor is often smoother than one which is less compact. A level floor with a smooth surface becomes polished with the friction of animals passing over it ; dirt, especially of a greasy nature, fills up the small pores on the surface, making it still smoother until it becomes glazed in much the same way as does wood that is dressed with wax and turpentine. A smooth hard surface is slippery to shod horses, whilst a smooth wet surface is dangerous to cattle.

especially if it is dirty. Accidents to horses and cattle on slippery floors are mainly due to the passage at the rear of the stalls being too narrow, to turnings near or at the doorways being too abrupt, and also to animals being hustled to and from a building A smooth impervious floor is not so dangerous if it is kept clean and if the animals are not hurried or frightened

For both economic and hygienic reasons a floor must be durable One that has been badly laid wears unevenly and subsides in patches If made of concrete on an unsatisfactory foundation it cracks and wears into holes, which give lodgment to water and dirt, and are a constant nuisance

For a floor to be free from damp it is necessary that it be above the surrounding ground Should, however, the ground be so sloping that the floor must of necessity be below the ground level outside at any part, then provision must be made for keeping out the damp by the formation of a "dry area" or by a special damp proof course If the floor is on the same level or below the outside ground it is always difficult to keep out damp A low-level floor is much more difficult to drain than one that is raised

Concrete—Of the materials commonly used for the flooring of animal houses, cement concrete is undoubtedly the best If properly laid and of good composition it is as durable as any other flooring, more impervious than most, and relatively as cheap If some powdered carborundum is mixed with the top half-inch or so of cement the surface is less slippery The bottoming of a floor is the same whatever material is used to cover it, and since the durability and, consequently, the hygienic condition of the floor depend very largely upon the nature of the bottoming, particular attention is paid to it

To ensure a satisfactory and lasting floor the earth must be cleared away to the necessary depth, which will vary with the nature of the soil, levelled off and well rammed until it presents a hard, even surface Having prepared the ground, a layer of hardcore consisting of stones or bricks broken so as to pass through a 4-inch ring is then spread to a depth of 6 inches or more, rammed lightly in order to secure insula-top It is important that this foundation should be well constructed for if badly laid it causes the floor to sink and crack It is of the greatest importance that the floors of animal habitations, particularly piggeries, be properly insulated This is often done by laying hollow terra-cotta blocks or land tiles between the concrete and the hardcore, the open ends of the rows of blocks or tiles should be sealed On the bottom of hardcore, with or without insulating bricks or tiles, is laid a 3 or 4-inch thick cement concrete floor, composed of one part Portland

cement, four parts gravel, broken stones or bricks and two parts sand, the whole being well mixed together with clean water. The concrete is then well beaten down, levelled off with a wooden float, which leaves a slightly rough surface, and left to set. It may be brushed with a stiff brush after it is levelled to give a somewhat rougher face. As concrete will absorb moisture from the ground, the flooring will be drier and warmer if the damp-proof course of asphalt from the walls is continued across the building under the concrete. In order to give additional foothold, the cement concrete may be grooved. The grooves should be at least half an inch deep and should, as far as is practicable, run at right angles to the direction usually taken by the animals when entering or leaving the building. Checkered grooving is not to be recommended as this renders the floor difficult to clean ; indeed, grooving should be avoided as much as possible. Should a finer and more durable surface be desired than is given with cement concrete, the upper inch or inch-and-half may be composed of two parts of crushed granite and one part Portland cement, with a little clean sand to fill the voids.

While cement concrete undoubtedly forms the best flooring for cow-sheds, piggeries, etc., some are of the opinion that it is too slippery for horses owing to its smooth surface and because, even when well grooved, the grooves in course of time become shallow and worn away by the friction of the horses' shoes. Nevertheless, cement concrete has been found to give complete satisfaction in commercial stables for heavy draught horses.

Concrete floors that have become smooth and slippery through wear and polishing may be roughened by the application of commercial hydrochloric acid. The method, which was devised by Scriven and Kenny,* is said to be effective and cheap, and capable of being carried out by the available farm labour. The standings and gang-way can conveniently be treated in sections with a surround of puddled clay. Though undiluted crude commercial acid may be applied, 25 per cent. strength left on for a period of approximtely 20 minutes will generally be found to give satisfactory results. After treatment the surface should immediately be flushed with water, and finally any residual acid should be watered with a solution of soda. Drain inlets must be closed with puddled clay to prevent acid entering the drains before it has been neutralised. After the treatment has been completed, it will be seen that the acid by eating away the superficial calcium carbonate will have left a nicely roughened surface, the sand and granite being unaffected. Workmen must be warned regarding the

danger of careless use of the acid, and they should be provided with rubber boots and mackintoshes All windows and doors must be kept open, as the fumes from the acid are noxious

Where a concrete floor gives trouble by "dusting" it may be treated with sodium silicate (1 gal 42 Baumé +4 gal of water) or magnesium fluosilicate (1-2 lbs per gal of water) the solution being brushed over the surface Two or more applications are needed, and after allowing each treatment to dry, the surface must be scrubbed with water before another solution is applied *

Other more or less satisfactory paving materials are causeway setts, and vitrified paving bricks *Causeway setts* may be either of whinstone or granite They are made in various sizes to suit a variety of purposes and local customs The causeway setts should be laid in a cushion of sand on a concrete bed from 4 inches to 6 inches thick The joints should be grouted with sand and cement, or with pitch Sometimes the joints are grouted for about two third of their depth, the remainder being filled in with pitch Granite setts give a good foothold when first laid, but tend to become slippery with wear

Vitrified paving bricks are laid in the same way as setts They wear very well but are always slippery They should be grooved to give foothold, the groove in each brick being fairly deep and wide, a shallow narrow groove serves only to collect dirt The bricks should be placed so that there is a continuous uninterrupted line of grooving

Ordinary building bricks, though frequently used in byres and piggeries, are too porous to make a satisfactory flooring material, and being comparatively soft they wear very unevenly They are cheaper than vitrified paving bricks and are less slippery If used, they should be placed on their edges and be set in cement

Wood, in one form or another, occasionally forms part of the flooring of an animal house It is scarcely necessary to say that wood is quite unsuitable for this purpose Even hard wood blocks absorb water, as also do creosoted railway sleepers

Composition bricks made of cork and pitch are sometimes recommended for the flooring of cow stalls and for beds in piggeries

Rubber has been used to some extent for the covering of floors in animal houses, but it has not proved as yet to be thoroughly satisfactory and resiliency, which no other type of flooring has This is an asset of very great importance because when cattle, and young in calf heifers in particular, are brought in from the fields in the autumn, a concrete floor proves unpleasantly hard and unyielding, and as a result swollen

*Shillinglaw Hale and Sharf   *Canad Dairy Ice Cream J* , 18, No 7,
see *Dairy Sci* , *Abs*, J No 3, p 232.

knees and hocks commonly develop, with frequently serious conse-
quences from secondary infection.   These accidents are liable to occur
even when a bed of straw is provided.

Rubber has been used in three principal forms, rubber blocks,
rubber mats and as rubber plastic flooring.   The blocks are made of
cement with rubber on the upper face, keyed into position on to
concrete.   The blocks are laid on to a cement floor and joined with
liquid cement.   This type has not been found to be very satisfactory,
because when weight is put on the blocks the edges of the rubber are
torn apart owing to its resiliency, with the result that seepage of
urine, wash water, etc., finds its way underneath the blocks.

With rubber mats the disadvantage of seepage does not occur, but
it has been found very difficult in practice to fix them to the cement
and they tend to lift at the edges allowing urine, dirt, etc., to work
underneath.

Both blocks and the mats become very slippery when wet, even
when covered with bedding.   This slipperiness can to a certain extent
be minimised if the surface is studded, or ridged and grooved.

Rubber plastic flooring, which consists of a mixture of powdered
rubber, powdered asbestos, cork, marble and granite chips and cement
and rubber latex, is the most promising of the three forms.   It is
warm, very resilient, impermeable, free from joins and is durable.
This material possesses the further advantage that when areas become
worn, they can be cut out and re-laid with new plastic with satisfactory
results.

Rubber flooring is not suitable for commercial horse stables owing
to the hard usage it would receive and the consequent replacement
which this would involve, but the plastic flooring has been strongly
recommended for dairy cattle standings.*

DAMPNESS IN BUILDINGS AND ITS PREVENTION

Dampness in walls and floors is usually due to bad construction and
neglected repairs.   It may arise from leakages from the roof, or the
wall surfaces, or from the absence of damp-resisting courses.   Even
where a damp-resisting course exists, its presence is very often nullified
by the outer ground being piled against the wall above the damp-
resisting course level.

Leaky Roofs.—A slate or tile displaced or missing from a roof will
form a direct inlet for rainwater, which runs down the roof boarding
to the wallhead, where it spreads in every direction, soaking the wall.

*Fowler, A. B. (1938).   The use of Rubber and Rubber Plastics
for Byre Flooring   Scot. J. Agric. 21, No. 2
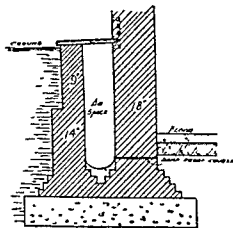
Fig. 52—Section through a wall abjoining high ground with a dry area covered and ventilated, which for preference should be made wide enough for cleaning out.

Succeeding frosts and thaws expand the moisture and displace the stones or bricks and mortar, every frost leaving wider gaps for a more powerful attack during the next frost. Roofs of all kinds should be examined regularly and repairs made without delay.

Damaged Gutters and Rain-Pipes.—Broken, cracked or choked gutters in roofing are also disastrous to the security of the building if neglected, as water not only runs down the wall face but lodges round the foundations, further aggravating the damp in the walls, which ultimately spreads to the flooring inside the building All rain conductor pipes should be examined carefully for cracks These cracks often take place on the surface of the pipe next the wall, and are not easily observed. Such cracking sometimes originates from a choked bend at the foot of the conductor pipe, causing the pipe to stand full of water, which becomes frozen, expands, and thereby does damage. The absence of gutters and down pipes is always false economy.

The Absence of Damp Courses—The damp-resisting, or, as it is often called, "damp-proof" course in a wall will be of little use unless it is of the proper type and in the right position. In erecting a new building care should be taken to keep the damp-resisting course above ground level and below the floor level, where possible. The wall should be carefully levelled and made free from loose, rough stones, bricks or pebbles. Everything sharp, which is likely to cut through the course after pressure is brought to bear upon it, should be carefully removed. It is a good plan to level-up in preparation for the damp-resisting course with a coat of cement mortar, finished smooth.

Fig. 53—Section of a retaining wall with cement or rock asphalt vertical course and asphalt damp-proof course Note the field drain covered by dry stone infilling.

Two courses of slates in cement, the slates being laid so that they break joint, is one way of preventing

the rising of the damp, but the slates are liable to crack in case of unequal settlement of the building.

Mastic rock asphalt, laid in two layers of ¾ inch each, forms a very good damp-proof course. The ordinary tar asphalt is cheaper but is not so effective. Lead is an ideal material, but cost prohibits its use. Purpose-made glazed earthenware tiles, bedded and pointed in cement, are occasionally used. They are impervious, and sometimes perforated in order to act as a means of admitting fresh air to the underside of wooden floors.

A very common type of damp-proof course is one consisting of bituminous sheeting with a thin lead core which, being flexible, is not affected by any unequal settlement of the building.

Retaining Walls.—On some sites it is impossible to avoid the ground being higher than the floor level at one or more sides of the building, and where this state of matters exists the wall supporting the high soil is known as a "retaining wall." In such cases the earth or rock should not come in direct contact with the wall of the building, otherwise it will be impossible to prevent surface water and subsoil water running from the higher ground to the retaining wall, which will act as a dam and consequently always be in a wet state. There are various methods of preventing or curing such dampness. The simplest is to form a trench down to the level of the bottom of the foundation, laying a field drain with proper runs and outlet at the bottom, and
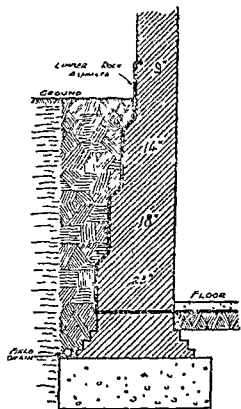
Fig. 54—Type of retaining wall for a building with very high adjoining ground. The damp-proof course is carried under all the floor and jointed carefully to the vertical asphalt.
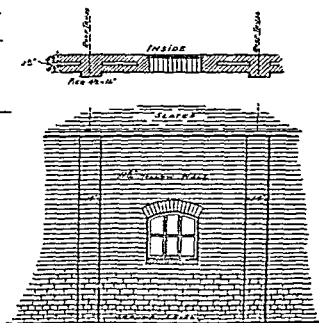
Fig. 55—Plan and elevation of a 12 inch thick hollow brick wall with piers outside and occurring at each roof truss.

Fig 56—Plan of 16 inch thick hollow brick wall with piers on inside face

filling up the whole space with clean, dry, broken stones or bricks, which should be carefully hand packed The top of these stones at the ground level should be covered with cement concrete, extending the full width of the trench. An additional precaution may be taken by coating the whole outer surface of the wall up to and about 6 inches above the ground level with Portland cement plaster, preferably treated with a good waterproofing liquid, or, alternatively, the same surface may be covered with vertical asphalt, although such work is not worth executing unless the material used is mineral rock asphalt, and this method is probably too expensive

A method which may be adopted for new retaining walls is to build the wall hollow, particularly in the case of brick walls, or to form an outside dry area as wide as possible by building the actual retaining wall clear of the building. The bottom of this area should have a properly constructed cement or tile channel, which must be below the floor level and damp course level, having proper outlets for any water which may gather, the outlets being arranged in such a way that chokage is impossible Such dry areas may be either covered over at the top and properly ventilated or left open where windows are required in the wall of the building below ground level Figures 52-54 show various systems which may be adopted

Rain Damped Walls —Walls exposed to the prevailing wet wind are usually damp during the rainy seasons. In new buildings this danger may be provided against by building the wall hollow, covering the outside with a coat of cement plaster waterproofed with a good waterproofing solution, or by covering the outer surface of the brick wall with slates or tiles nailed to creosoted wood battens Hollow brick walls should be carefully built The outer thickness need not be more than $4\frac{1}{2}$ inches if built in cement, the main part of the wall being inside This arrangement provides a substantial support for the roof, and bears the wear and tear which is constant inside agricultural buildings The cavity between the outer and inner walls should
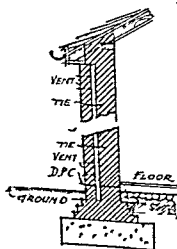
Fig 57—Section of hollow brick wall with ventilation of cavity by gratings

be about 2½ inches, properly ventilated at the top and bottom, with galvanised louvred gratings to prevent the entry of rain and vermin. Galvanised malleable iron ties must be carefully built between the wall and its outer casing, using at least two ties to every superficial yard of work. These ties have a twist in the middle to prevent moisture from travelling across to the inner wall. During the erection of hollow walls, care must be taken that the mortar does not drop down on to the ties nor to the bottom of the cavity. This may be prevented by hanging laths in the cavity, and drawing them up as the building proceeds. Hollow walls are doubly beneficial; they afford a reliable method of avoiding rain penetration and give better heat insulation than the corresponding thickness of brickwork in solid walling.

SURVEYING EXISTING BUILDINGS FOR THE PREPARATION OF SKETCH PLANS TO ACCOMPANY A REPORT

The appliances necessary to make a survey of existing buildings are as follows :—a 50 feet or 60 feet tape ; a surveyor's 6 feet rod; a 3 feet rule ; a plumb line ; a survey book consisting either of ruled or plain paper, and a pencil. An intelligent and energetic assistant is indispensable.

Before starting to take measurements, a preliminary examination of the general arrangement of the buildings should be made, and their principal details of construction noted. If a group of buildings is to be surveyed, a start should be made with the largest and most regular of the structures, having a long, straight wall such, for instance, as the main cow-shed. (See Fig. 58.) This will form a base from which diagonals and tie measurements may be taken to fix the relative position of the various buildings on paper. Care should be taken, in sketching out the plan of the building to be measured, that sufficient space is left on the page of the survey-book to take in all the connections or out-lying features. Details such as doors, windows, fittings, etc., should not be sketched in before the whole of the outer walls of the building are shown on the plan.

Squared paper is recommended for sketch surveys.

It is necessary to see that the proportion of the building is fairly accurately represented in the sketch. System must be followed in taking the measurements, if errors, and consequently additional visits to the building, are to be avoided. The outside dimensions of the buildings should be taken on all frontages, starting at a corner and reading off running measurements to the full extent of the tape if necessary. That is to say, the ring of the tape is held on a corner, whilst the daylight sizes of each window and door opening are taken
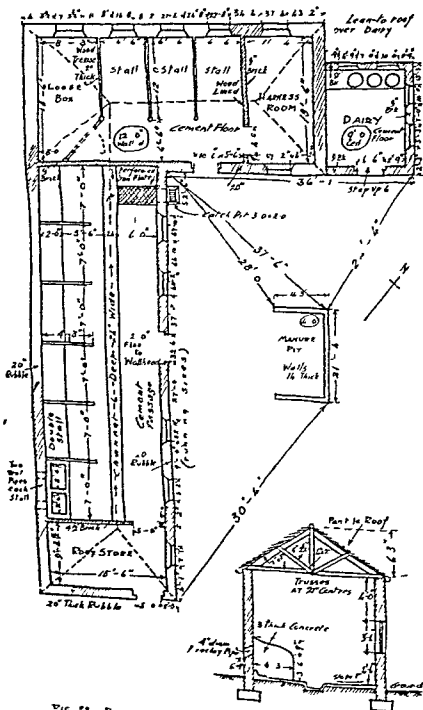
FIG. 58.—Reproduction of a survey sketch showing the method of taking measurements, etc.

and entered upon the sketch-plan, using arrow-heads to denote the direction and point of measurement.

The inside dimensions of each apartment should be taken, measuring along each wall and taking the diagonal measurements from corner to corner. All doorways, windows, chases, breaks, stalls, gutters, roof principals, roof lights, hatches, ridges, etc. should be measured from definitely fixed points by running measurements, and marked carefully upon the plan, bearing in mind that these measurements are to be transferred to a plan drawn to scale.

Each storey should be measured in a similar manner, and the direction of the floor joists shown clearly in every case.

Sketches should be made of each elevation of the building, and the heights of all openings and details of the doors and windows, pipes, roofs, etc. measured and shown upon the plan and elevations. A cross-section, no matter how rough, should also be sketched and all the principal heights measured and shown.

In measuring elevations the floor level at a doorway can be used as a datum line from which ground levels and the position of sills and lintels can be measured. The thickness of all walls and partitions, and the materials of which they are composed, should be noted, and the description and condition of floors, roofs, walls and fittings should be jotted on the side of the drawings, with arrow-headed lines indicating the parts to which each note applies.

If a drain plan of the existing premises is not available, all the drains should be carefully surveyed, the depths and position of man-holes noted, and the direction of flow marked upon the survey plan.

After the survey has been completed, entries should be made in a notebook, systematically and under proper headings, of the condition of all parts of the building, noting particularly those parts which require repair, and the details of construction in buildings which are to be altered. A carefully made survey is always worth the time spent upon it. Fig. 58 is a reproduction of a simple survey sketch embodying the points to which reference has been made.

HOPPER WINDOW

CEMENT WASHED BRICKWORK

CEMENT PLASTER

CAST IRON PLATE

KICKING PANEL

4 3 6"

18"

10"

AIR INLET
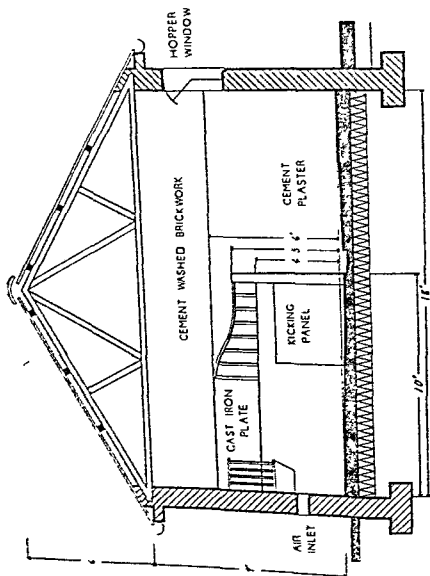
Fig. 60.—Single row stable suitable for heavy draught horse

HOUSING OF HORSES

The traditional practice of confining farm horses in stables is tending in some districts to give place either to the keeping of the horses in open yards with shelters or, in the milder parts of the country, to running them in paddocks throughout the year. Those who follow the open air system are satisfied that their horses are healthier, an opinion which is endorsed by veterinary experience. It must not be inferred from this, however, that the open air system is likely to be suitable for all parts of the country at all times of the year. On the contrary, for a number of reasons the housing of horses in stables will continue to be a feature of horse management.

The planning and fitting of a stable depend upon the number and class of horses to be housed, but simplicity should always be a ruling factor in construction. Where accommodation for a few horses only is required, the stalls are best placed in a single row along one wall (see Fig. 59). For a large number of animals, a wide stable having two rows of stalls and a passage running down the centre of the building between them is more convenient. The stalls should be constructed so that the animals face each other, nor should they be placed in transverse rows across the building.

Stalls. Fineness in allotment of standing space in the stalls is neither necessary nor desirable with horses, as is the case with cows, and it is better to provide stalls of a large size, since they can always accommodate small horses while small stalls will be useless for big animals. The object of providing a separate stall for each horse is that all may rest and feed in security and comfort, and be free from the annoying attentions of their neighbours.

The length of a stall from the facing wall to the heel-post of the stall partition should be 9 to 10 feet, the larger figure being suitable for horses of the heavy draught type, and the smaller for hunters, hacks, etc. Stalls are commonly made too short ; the length should be such that it is impossible for one horse to kick his neighbour when both are standing back in the stall. The width of a stall for a draught horse should be from 6 feet to 6 feet 6 inches, in order to allow the animal to lie down in comfort, and also to permit of its being turned round in the stall when being led out. A width of 6 feet will be ample for light draught and riding horses.

Passage. The passage behind a row of stalls, or between two rows of stalls, in a stable should be wide enough to permit the animals to turn without difficulty when entering or leaving their stalls. The width of

the passage must also be such that there is no danger of attendants being kicked when passing behind the stalled horses This passage should not be less than 6 feet wide for a single row stable, and 10 feet for a double stable

Dimensions of Stable. A single storey building with an open roof, i e without a loft, is preferable to one having a loft, since the latter presents difficulties in regard to ventilation and unless properly ceiled tends to make the stable dusty The height of a stable must give ample air-space for the animals, but it must not be so high that it allows expired air to become cooled and condensed before it gets an opportunity to escape from the building If the stable has a closed roof, i e has a loft or other storey above, the height from the floor to the ceiling need not be more than 12 feet , with an open roof, the total height from floor to roof ridge should not exceed 15 feet

If the air-space of a closed roof single row stable be calculated from the following dimensions stall 10 feet from wall to heel-post and 6 feet wide, passage 8 feet wide, and height of building from floor to ceiling 12 feet, it will be found to be 1296 cubic feet From this must be deducted 20 cubic feet for the space occupied by the horse, leaving a net air-space per animal of 1276 cubic feet, which is about the optimum air-space usually considered to be necessary The floor space of a stable having these dimensions is 108 square feet per animal, or one-twelfth of the total number of cubic feet of air-space

If, on the other hand, the stable is open to the roof, the height of the walls should be approximately 9 feet, and with a single stable having an inside width of 18 feet, the height from the ridge to the level of the eaves would be 6 feet The air-space of such a building, after making deduction for the space taken up by the horses, will also be 1276 cubic feet per head

Ventilation and Lighting. The ventilation should be planned and constructed as recommended in the section dealing with that subject Inlets in the form of air bricks, or gratings, under the mangers at 2 feet above floor level, and capable of providing 7 square inches of inlet per horse, are desirable ; hopper windows, preferably with side wings to minimise draught, will also serve as additional air inlets Outlet ventilation may be by raised ridge tiles, extractor cowls, or louvre boards In a single stable, air bricks should also be placed in the back wall just above ground level to assist in keeping the floor dry

As a means of natural lighting, fixed roof-lights situated close to the ridge are the most effective The lights should face to the north or east, in order to avoid strong sunlight penetrating into the stable,

and so causing it to be uncomfortably hot for animals during warm weather. Where wall lighting is adopted, this should be by means of hopper windows, placed, in the case of a single row stable, high in the wall behind the horses. In a double stable, wall windows must of necessity be placed high in the facing walls; where possible, however, this type of stable should always be provided with roof lighting in preference to wall lighting.

With roof lighting there should be provided not less than 4 sq. ft. of glass, or in the case of wall windows 12 sq. ft., for each *pair* of horses.

Artificial lighting must always be from the passage behind the horses, and the source of light, whether oil lamps, gas or electricity, must be placed in such a position, or at such a height, as to be clear of horses moving into, or out of, the stalls.

Flooring. The flooring of the stalls and passages may be of Staffordshire blue paving bricks, granite setts or Portland cement concrete. The first two of these materials are very durable but rather expensive. Cement concrete at least 6 inches thick, with a top rendering of roughened granolithic 2 inches thick, will make a good standing and is relatively cheaper, but the rear 3 feet of the standing can with advantage be made of either of the other two materials mentioned in order to take the most severe wear. A floor of cement concrete alone will wear quickly, and is not advised unless a hard aggregate is used.

The stall floor should fall 1 inch from each side to the centre, and 2 inches from head wall to 1 foot behind the heel-posts, where a shallow gutter falling 1 in 60 should conduct drainage liquids to an outside gulley. The floor of the passage-way should likewise slope towards the gutter.

Walls. Walls should be strong enough to withstand kicking or rubbing by heavy horses, *e.g.* bricks 9 inches thick laid in cement mortar (not lime mortar), or concrete 6 inches thick if in mass form but less if reinforced. The insides should have a smooth hard surface so that they are easily cleaned and do not give lodgment to dirt and dust. It is unnecessary to go to the expense of lining the walls with glazed tiles or of building them with glazed bricks, but glazed tiles or bricks may with advantage be placed on the wall immediately above the mangers. If the walls are finished with a face of smooth hard cement to a height of 6 feet from the floor, and above that well pointed and washed over with cement, they will satisfy hygienic requirements.

All external angles such as those of doorways should be bullnosed

to a height of 6 feet, whilst corners at junctions of walls and floors should be filled in with cement so as to facilitate cleaning.

Doors. The doorways, of which there should be at least two in a large stable, must not be less than 4 feet 6 in., or 4 feet clear, in width, so as to lessen the risk of large horses injuring themselves when entering or leaving the stable.

The minimum height of a stable doorway so that horses may pass through it without any risk of head injury is 7 feet. It is an advan-
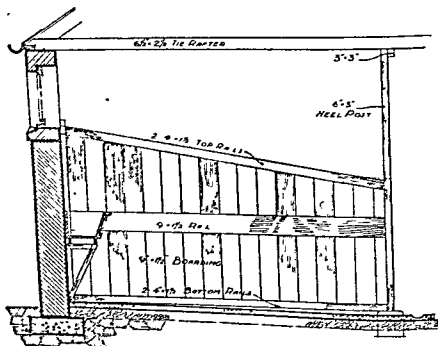
FIG 60.—Section of stable showing all wood stall division.

tage if stable doors are made in two parts cut transversely, the lower part being about 4 feet high ; all edges should be rounded. Doors should be hung on the outside, so that when fully open they can be fastened back against the outside face of the wall. All door fastenings should be of stout wrought iron without dangerous projections. Projecting latch fastenings may give rise to accidents through harness getting caught on the latch if the door has not been fully swung back.

Stall Divisions. Working horses require as much rest and quietness as possible during their stabled hours, and stall divisions should be constructed so that the horses cannot see or interfere with each other. The necessary height and length of the partitions will depend upon the size of the animals.

As has been stated, 10 feet is a desirable length of stall for horses of the heavy draught type, while 9 feet will do for smaller horses. The height of the partition at the rear of the stall need not be greater than will prevent a horse accidentally getting his leg caught over it ; 4 feet 6 inches will be high enough. It is not advisable to make partitions higher than is necessary, especially if they are solid throughout, since the higher they are the less free will be the circulation of air in the building. At the front of the stall the partition must be at least 1½ feet higher, i.e. 6 feet, in order to prevent adjacent horses from worrying each other by poking their noses over the top.

Stall divisions in the past have usually been made of 1½ to 2 inch wood boarding (see Fig. 60), but reinforced concrete or bricks are now sometimes utilised. A hardwood such as well-seasoned oak or elm is preferable to softwoods like pitch or red pine, which wear badly and require constant repairs. The latter also become rough, and are consequently difficult to clean and disinfect. Stall partitions have to withstand much hard usage, and at the rear of the stall they should be protected by mild steel plates 3 feet 6 inches wide and 3 feet high, securely bolted to the boarding. It is probably an advantage for the boarding of the partition to stop short about 2 inches above the floor. This allows a current of air to pass underneath, thereby facilitating draying of the standings, and also keeps the lower ends of the boards clear of the damp bedding and wash-water.

A modification of the complete partition which allows better circulation of air in the building is one where the upper part consists of iron bars, the boarding being limited to the lower 4 feet (see Fig. 59). At the front of the stalls the bars are best replaced with cast plating for a distance of about 4 feet from the wall. This prevents horses seeing one another and worrying at feeding time, and may also help in preventing the spread of respiratory diseases.

Heel-posts should be well sunk in the ground, have a broad base-plate, and be embedded in cement concrete. Where the heel-post is not continued upwards to form a supporting pillar for a roof, it should be finished off without any projection, not surmounted with a ball or other embellishment, as is often done, which is liable to catch some part of the harness, or which may lead to a horse injuring its head when being turned round in the stall. For the same reason there should be no brackets or hooks for hanging up harness on the heel-posts. Rings on each side of the heel-posts for the attachment of pillar chains should be placed at a height of 4 feet 6 inches from the ground.

Bails (from O. Fr. *baille*, a barrier). In place of a complete partition, swinging planks or poles, known as bails, are sometimes used in

3' × 3' × ¼"
METAL
HEADPLATE

WALL

OAK on ELM 2" THICK
7' 0" × 1' 0" EACH · BOARD

2' 0"

1' 0"

3' 0"
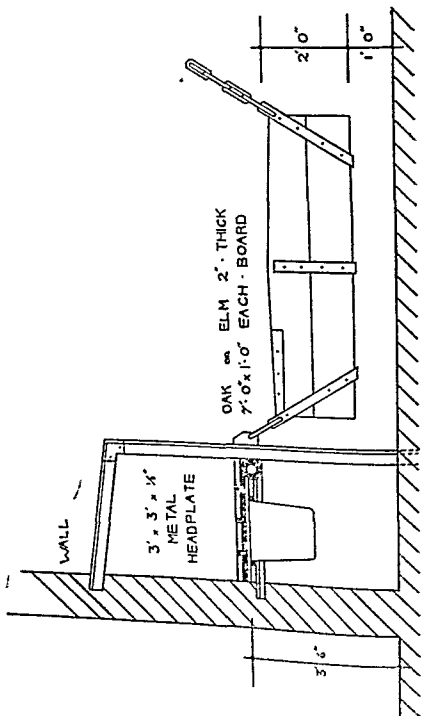
Fig. 61.—Bail for heavy draught horses.

military and in large commercial stables. The simplest type is in the form of an iron bar or wooden pole, slung by lengths of chain at about 3 feet from the ground from the manger in front, and either from the heel-post or an overhead beam at the rear; they have, therefore, a certain amount of lateral movement. Chains should be secured with safety catches so that they can be released quickly if an animal should get hung up on the bails.

Another type of bail, which is similarly slung, is made of elm or oak planking, 7 feet long and 2 feet deep, the front 3 feet of the top edge being sometimes covered with iron sheeting or zinc to preserve the wood from horses which might otherwise bite it. (Fig. 61.)

It is claimed that the bail system of separation allows freer ventilation than do closed partitions, that all horses are easily visible, that cleaning of the stable facilitated, and that the initial cost of bails is far less than that of partitions. On the other hand, bails have several disadvantages; horses may get astride them and suffer severe injury to the inside of their legs and thighs. A method sometimes adopted to lessen the possibility of serious abrasion is to cover the suspending chains with leather or sacking. Horses will the more easily get astride the bail if it be hung too low, while, if it is too high, injuries may arise from kicking under the bail. A serious disadvantage is that some horses may not lie down, usually because of the fear of having their feet and legs trampled. Young animals which have been injured in this way may never regain confidence to lie down, even when put in proper stalls or in loose-boxes. Finally, there is little doubt that bails are less conducive to that rest and comfort which is so essential for hard-worked horses when in the stable.

Mangers. The types in common use range from a plain wooden trough with a wood-sparred hay rack to the more hygienic cast-iron or salt-glazed mangers. Wooden mangers and hay racks are cheaper at first cost and for this reason will continue to be used where initial outlay has to be considered, but to offset this there comes a time when constant repairs are necessary. It is impossible to keep wooden mangers clean, and if wet foods, such as bran mash, are fed in them, they soon become sour and offensive.

Wooden mangers (see Figs. 62 and 63), when used, should be made of elm or oak boards, $1\frac{1}{2}$ to 2 inches thick. They should be about 18 inches wide at the top, 9 inches wide at the bottom, and about 30 inches long. The front board should slope inwards to reduce the chance of horses bumping their knees. Twelve inches is a sufficient depth for a manger. This will hold a feed of grain and chopped fodder without portions being tumbled out by the animal in searching for the

grain in the feed   As a safeguard against crib-biting the front o
breast-board of wooden mangers should be protected by an iron or m
steel plate fixed as shown in Figs   62 and 63   Zinc is often recon
mended as a covering   but unless the zinc is unusually thick it w
soon be bitten through by crib-biting horses and so present sharp jagge
edges   A thickness of zinc which would preclude the plate being bitte
through would be too expensive an item for most stables   The metho
indicated in Fig   62 is suitable for the installation of wooden manger
    properly made iron mangers are easily cleaned (Figs   64 and 65
and seldom need   repairing   There are many patterns now availabl
which have been designed with a view to utility and hygienic require
ments   A roller-bar fixed across the manger a few inches from eac
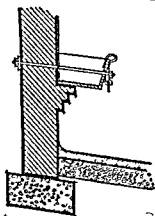
FIG   62—Section showing a
      wooden   manger   with
      corbelling and lie bolt.
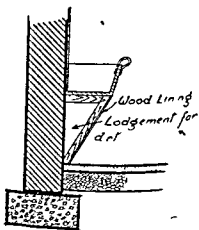
FIG   63—Section showing a
      wooden manger boarded n
      below

Wood Lining
Lodgement for
   d f

end will effectively prevent horses from tossing out the food   An over
hanging inside lip, which is sometimes recommended for the same pur
pose, is undesirable, as it interferes with the efficient cleaning of the
manger   The front of the manger, if broad and rounded, tends to
discourage horses from crib biting   A drainage hole, with stopper
in the bottom of the manger   makes for easier washing out of the
manger pan, as also do rounded inside corners and angles
    An improvement on the iron manger is the salt-glazed fireclay type
These are for all practical purposes completely resistant to the erosive
action of foodstuffs or saliva, and do not become pitted as does the
iron manger after long usage
Hay Racks.   At one time hay racks were invariably placed over the
manger at a level higher than the horse's mouth, and though still
sometimes found in farm stables and in old commercial stables, this
position has been rightly abandoned for a better position at a lower
  el   Overhead racks are reported as a frequent source of eye injury

through seed and debris dropping into the eyes as the horse stretches up his head to pull out hay. When fodder is stored in a loft over the stable, the high rack no doubt effects some saving of labour, in that long hay can be pushed through a trap-door immediately above the rack, but this is no compensation for the risk of eye injuries.

The best place for a hay rack is probably just above the level of the manger. (See Fig. 65.) The wide topped rack below the level of the manger shown in Fig. 64, has the disadvantage that it allows large bunches of hay to be pulled out and then dropped on the ground. To obviate this, such racks may be fitted with a grid over the hay, which
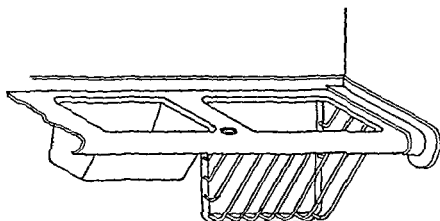
FIG. 64.—Cast iron manger with low level type of hay rack.

falls as the hay is eaten, thus keeping the fodder in place, but always within reach of the horse.

Water Pots. There is a difference of opinion as to whether stabled horses should have access to a supply of water at all times or not. There can, however, be no question that on physiological grounds a supply of fresh water should always be available to horses. Unfortunately, in practice, a fixed water pot soon becomes fouled with the grain and fodder which the horse drops into it during feeding and drinking. The food in the manger also tends to get wet by splashing when the horse is drinking or by water conveyed to it by the animal after drinking. If a water pot forms a part of the manger fittings, it is necessary that the pot be cleaned out daily. In commercial stables however, there is usually little time or labour for carrying out this essential requirement, and for this reason a constant supply of water in front of the horses is not recommended for this class of stable. In private stables, and where plenty of labour is available, water pots cannot be objected to on the grounds stated.

A *hygienic* and *useful* water-fitting is a bucket supported in position by an iron ring fixed in the wall. The bucket is easily removable for cleaning and, if water is not laid on to each stall, it

can be filled at any tap A good type of bucket holder is one in which the iron ring is hinged near its attachment to the wall thus allowing the ring to swing up and fit into a recess in the wall when the bucket is removed

There is no objection to the use of non removable water pots in loose boxes, since, because of the greater wall space available, they can be placed well away from the manger Loose-boxes used for sick animals should always have some means of providing a constant supply of fresh drinking water
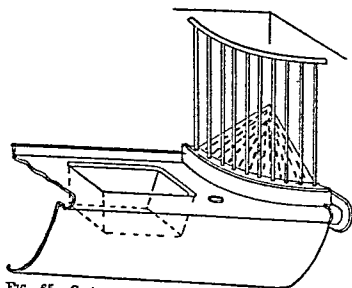
FIG 65.—Cast iron manger with hay rack just above level of manger

Water-Troughs It is often argued that when horses are watered in the yard at a common trough they are more likely to contract disease from one another This is no doubt true, but on the other hand it is a recognised rule of stable management that if an infectious disease, such as influenza, makes its appearance in a stable or in a town, common water troughs should be temporarily closed and each horse supplied from its own bucket

In spite of the obvious objections which can be raised against common drinking troughs, they have the advantage in utility stables that single watering source is more likely to be regularly and thoroughly cleaned than are individual receptacles in the stalls In large commercial stables, too, its state of cleanliness can readily be seen at all times by the stable foreman or overseer

A water trough should be placed out of the way of dust traps, such as are naturally formed at the end of a yard opposite the entrance gate The top of the trough should be about 3 feet from ground level,

if lower than this, loose harness and collars will slip down when the horse is drinking. The trough should be emptied once daily for cleaning and should be well scoured out once a week.

Water-troughs are usually provided with a self-regulating ball-cock, which is placed in a separate chamber and covered in by a metal plate.

Stable Fastenings. Horses must be fastened in their stalls in such a manner as will prevent them getting loose, or from standing too far back so as to expose them to risk of injury from their neighbours. At the same time it must be possible for them to feed and to lie down in comfort, without the risk of becoming entangled by the securing rope. This is effected by having the head-rope just sufficiently long to enable the horse to lie down in the stall with his head resting on the ground. The rope should have a counterpoise weight attached to its free end, so that when the animal rises the loose rope is taken up and does not hang in bights, being always in a sufficient state of tension to prevent its getting over the horse's head or under his legs. A one-pound weight is heavy enough for the purpose. The correct length may be ascertained by allowing the horse to stand naturally in the stall well up to the manger, and letting the counter-poise just rest on the ground. Ropes, chains or leather straps, or combinations of these, are variously used. Chains are economical in wear, but are noisy and are difficult to release in cases of emergency. Ropes are not noisy, and are quickly cut in the event of fire or of a horse getting tangled up in the headrope.

The free end of the head-rope may pass through a ring attached to the front of the manger at its centre, and so hang directly under the manger, being kept taut by the counterpoise weight. As horses, especially idle or lightly worked ones, frequently acquire the habit of picking up the rope with their teeth and tossing the weight into the manger, or getting it twisted round the rope, it is an advantage to have both weight and rope enclosed under the manger with the rope running through a slot in the manger-plate. In order to keep all weight off the horse's head when feeding or standing up in its stall, a stop ring placed on the rope about a foot from the head-collar is useful.

The top of the manger placed 3 feet from the ground will be found a convenient height for the average horse, or 3 feet 6 inches for large Shires. The boarding-in of part of the space below the manger, and formed by its bottom and the wall as shown in Fig. 63, is not recommended. Although this may offer some protection against injury to knees on the front bottom edge of the manger, space so enclosed provides a harbour for dirt and for rats, mice and vermin.

Some horse owners prefer to place mangers on the ground, the contention being that this situation allows horses to feed from a more natural position

Loose-Boxes   Whatever the number of horses kept, at least one loose-box is necessary where the animals are ordinarily accommodated in stalls   If possible loose-boxes should be built outside the stable proper, at some distance from it and out of the track of horses passing to and from work   One or more boxes may also with advantage be included
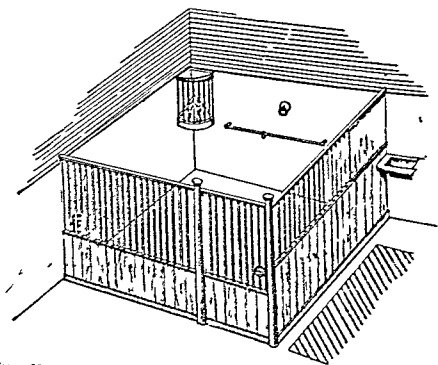
FIG 66 —View of an internal loose box showing fittings   The manger is in the corner opposite the hay rack   Note horizontal bar with sliding ring on back wall

within the stable in addition to those outside, but where it is not possible to have both inside and outside boxes   preference should always be given to the latter   Most racing and some hunting stables are entirely comprised of loose-boxes

Internal Loose Boxes —Boxes within the stable are usually placed at the end of a row of stalls and will thus usually follow the width of the building. They must be of an area which allows considerable freedom of movement, for ordinary purposes a box about 150 to 160 square feet will be found ample   Seven feet is a suitable height for loose box partitions   Wooden panels surmounted by open rails (see

Fig. 66) are preferable to complete partitions since this allows a better air circulation; animals can also be seen without disturbing them by opening the door. The wooden parts of the partition separating the box from the adjacent stall should be about 4 feet in height; those of the door and passage partition need not be higher than 3 feet. The bars at the head of the adjacent stall should be covered with iron sheeting as already recommended for stall fittings. The door of the box must have a minimum width of 4 feet clear and should be hung to open outwards. If hung the reverse way, the litter in the box will get pushed up and caught under the door when the latter is opened. Another consideration is that if a horse becomes cast in the box, as may easily happen in the case of colic, and is lying across the doorway, it will be impossible to open the door unless it is hung in the recommended way. The door fastening should be of the safety type in which the latch slides out of sight when the door is opened; it must be capable of being opened from without or within the box. The manger, hay rack and water receptacle are best placed in separate corners.

In the past it was sometimes recommended that the inside of the external walls of loose-boxes be lined with wood to a height of 4 or 5 feet for giving greater warmth to the box. This is not necessary, and indeed for sick boxes the practice must be condemned owing to the increased difficulty in cleaning and disinfecting which it involves. Cement plaster is always to be recommended on hygienic considerations for facing any interior wall.

A good method for fastening a horse in a box is a horizontal bar running between the manger and hay rack and on a level with them. The bar carries a sliding ring to which the head rope is tied, thus allowing the animal to move from manger to rack as he may desire. A ring, fixed at about 5 feet 6 inches high in the wall, makes a convenient tie for grooming.

The drainage channel from the box may pass under the door, or under the partition, whichever is the more convenient, to join the main channel. The floor should be of concrete, Staffordshire Blue or other hard-wearing brick, grooved on the surface and falling away from the walls and partitions towards the channel. Adequate lighting and ventilation should be provided.

External Loose-boxes.—External boxes may form the main stable accommodation as in racing and hunting establishments, or in the case of commercial stables be built solely for emergency purposes, such as the reception and isolation of the sick. In every kind of stable there should be one or more boxes, situated at some distance from all other

horse accommodation, for the purpose of segregating actual or potential cases of infectious disease.

In general, the features of an outside loose-box are the same as those of an inside one. Woodwork should be dispensed with where possible, and the walls lined with smooth-finished cement to a height of at least 6 feet from the floor. Above this, the bricks or stones should be well pointed and washed over with cement, but need not have such a highly finished surface as the lower part. Bearing in mind that outside boxes are to be considered primarily as hospital accommodation, special care must be taken to ensure easy and efficient cleansing and disinfection—hence the substitution of smooth cement for wood lining. For the same reason all internal corners and angles should be filled in with cement. Manger and other necessary fittings must be of the simplest character, and in at least one box these fittings should be removable for the safer reception of colic cases. Doorways should measure 7 feet by 4 feet, and the door made in two portions, divided horizontally, the lower being 4 feet 6 inches in height, each part opening back flush with, and fastening securely to, the outside wall by a hook. A steel angle screwed to the upper edge of the lower portion will prevent horses from damaging the wood by gnawing and biting it. Most horses spend considerable periods with their heads over the lower door, and, therefore, under ordinary circumstances the upper door should be fastened back throughout the day, and probably also during the night, so as to allow the inmate of the loose-box as much fresh air and sunlight as possible. As some horses develop the habit of pawing at the door, it is an economy to have the inside of the lower portion lined with sheet iron. The hinges of doors on outside loose-boxes must be carefully made, of the "crook and band" type, with the bands extending at least half the width of the door, and the crooks well tailed into the wall.

At least one loose-box in an establishment of any size should have an overhead beam fitted with a lug bracket from which a horse can be slung.

Harness Room. It is always desirable to provide a room in which to store harness, clothing and grooming kit, adjacent to and entered from the stable. The size of the harness room, which must be dry and well ventilated, will depend upon the number of horses for which the stable is designed. The walls require to be lined throughout with match-boarding so as to protect the harness from damp where it hangs against the wall. Artificial heat, such as a fire, stove or radiator, is desirable so that the harness may be kept dry, and so preserved from the action of moulds when not in every-day use. For commer-

cial stables, lockers about 2 feet high by 1 foot 6 inches wide placed round the wall are indispensable, one being allocated to each horseman for storing his own grooming tools, etc. When closed, the lockers serve as seats on which the men may sit when polishing harness, etc. Harness can be hung above the lockers on brackets and hooks. A suitable height for a saddle-bracket is 5 feet, and for a collar-hook 7 feet, above the lockers. Saddle-brackets should be placed about 3 feet apart with a collar-hook midway between each pair of brackets. A dry cupboard should be provided for storing rugs, bandages, etc., which must always be carefully dried and aired before being put away. A cupboard, which like the clothing-store should be kept locked, is useful for storing medicine and first-aid dressings.

On farms where a separate harness room is not always provided strong brackets, securely fixed to the back wall of the stable, are used for head-stalls, collars and other harness in every-day use. Where this procedure is followed, the minimum width of the passage should be 7½ to 8 feet in order to allow for the gangway space neutralised by the projecting brackets and harness.

Food Store and Food Preparation Rooms. In small stables a special food preparation room is not an essential feature ; corn, chaffed hay, etc., required for day-to-day use should be kept in rat-proof, metal bins, which may be located in the stable passage, provided the latter is wide enough (minimum 8 feet) and provided the bins do not cause interference with the free use of the gangway. A separate hay store for horses is not necessary on a small farm. In a large stud, as for example commercial or railway stables, where feeding requirements involve large amounts of corn and other feeding stuffs, a damp-proof and rat-proof grain store must be available, together with storage for hay and suitable accommodation for the mixing and preparing of food. The equipment necessary for food preparation in any large horse establishment includes a chaff-cutting machine and an oat-crusher.

STABLING AND MANAGEMENT OF HORSES IN COAL MINES.

The use of horses in coal mines is governed by the Coal Mines Act, 1911, and more particularly by the Third Schedule to the Act, which sets out in detail the regulations to be observed in the care and management of horses.

The Third Schedule provides that no horse shall be taken into any mine until it is four years old, and has been tested for, and certified to be free from, glanders by a veterinary surgeon Stables must be properly constructed, separated from haulage and travelling roads, and continuously ventilated with intake air Roof, walls and partitions, unless painted, or made of slate, tiles, glazed brick or iron must be lime-washed at least once in three months A sufficient supply of food and water must be provided daily for each horse while in the stable and at work Horsekeepers are appointed in writing by the mine manager in the proportion of one to every fifteen animals A suitable supply of medicine and dressings and an appliance for destroying horses must be kept available for use No horse may be allowed to go to work in an unfit state, or improperly shod, or otherwise than with properly fitting harness, including a guard for the eyes No blind horse may be worked in a mine The driver shall remain in charge of the horse while at work, and shall at the end of the shift, unless otherwise ordered, return the hourse to the horsekeeper at the stable. Drivers are required immediately to report any injury to a horse, any insufficiency of food or water, and any case where the harness rubs against the roof or sides, or any case in which the harness is defective Every official and horsekeeper shall report to the manager or under-manager any illness or injury, or any marks of ill treatment or over-working of any horse, and any defects in harness likely to cause pain or injury A horse about which such reports are made shall not be allowed to go to work until authority to that effect is given by the manager or the undermanager Horsekeepers keep a report book, in which a daily record is made of the condition of each horse, including the time absent from the stable, and the name of the driver in whose charge it has been Separate pages are provided to enter particulars of any accident or illness affecting any horse The manager is held responsible for the exercise of such supervision as is necessary for the observance of the provisions of the Act

It is usual to appoint a head horsekeeper to whom all horsekeepers are responsible, and whose duty it is to visit all stables in the pit and see every pony daily. These men exercise a general supervision, keeping the agent and managers informed of all matters affecting the welfare and efficient management of the ponies They also keep in close touch with the veterinary surgeon and are responsible for carrying out his instructions

The location of stables in a mine is governed largely by the question of convenience, whilst their actual construction is influenced by mining conditions which are of course the province of the mining engineer Occasionally, to avoid excessive travelling by the ponies, it is necessary to build stables at some distance from the shaft, but, so far as is possible, stables are usually situated close to the shaft

The site for a stable is prepared so as to allow a man to work at his full height, and to afford a passage of about six feet behind the stalls. When this has been done, retaining walls of brickwork are built along the sides of the prepared site. The heel post of the stall consists of a brick pillar carried

up to the roof. This pillar, together with the front and rear walls, serves to carry the steel girders by which the roof is supported. Mangers are formed in brickwork, and lined with cement, or earthenware. Stall divisions are usually built of brick to the full height at the mangers, but only to half the height between manger and heel post. The space thus left is filled by two or more iron rods. The division is therefore fully effective as a partition, but it also offers the least possible obstruction to the ventilation. The rear wall of the stable contains a recess behind each stall for the accommodation of harness.

Floors are laid in concrete where possible, but in some cases where ground movement is experienced it is necessary to resort to bricks laid on edge. Whenever possible stables are lighted by electricity and water supplies are laid on for drinking and washing. Provision is made for the storage of food, harness, and the necessary first-aid medicines and dressings. At least one loose-box should be provided for the accommodation of sick or injured ponies. In many of the mines in the North of England it is necessary to wash the ponies on their return from work. This may be accomplished by constructing a bath near the stable, through which the ponies pass. The final washing is completed with the aid of a hose-pipe in a part of the stable set aside for the purpose.

Food is supplied to the pits from a central store, already prepared according to the method of feeding in use. Part of the ration and a supply of water is sent into the workings, for consumption during the shift. Feeding boxes are maintained in the workings for the distribution of food to the ponies.

In the North of England ponies are usually divided into two classes according to the work to be performed:—

(1) *Putting Ponies.*—The small putting pony works close to the coal face, and hauls a small number of tubs, usually one or two, from the working places to a point where larger numbers are collected by the driving pony.

(2) *Driving Ponies.*—These are larger animals, used to haul the coal from the point where it is left by the putting ponies to the main system of mechanical haulage. The number of tubs hauled by these ponies is naturally greater, and the distance may be longer.

The usual method of harnessing ponies is to use a set of cart harness with certain modifications to make it adaptable to the use of limbers, which the pony carries about with him. The limbers consist of a pair of shafts, connected at the rear end by a rounded iron bow, having a projecting neck for attachment to the tub. There are the usual three hooks for the attachment of shoulder chains, backband, and breeching chains, and the bow of the limber is supported by straps extending from the croup to rings fixed at the rear end of the shafts. These bearer straps carry the weight of the limber, and prevent it from falling on to the pony's legs when the animal is not attached to a tub. Open-top collars are used, and the usual bridle is modified to provide protection for the poll, and guards for the eyes. In some cases, or for special purposes, ponies are worked in chains. This harness closely resembles that used in the plough.

HOUSING OF DAIRY CATTLE

Systems of Herd Management for Milk Production. The first consideration in connection with the housing of a dairy herd is to provide accommodation for the cows where the production of clean milk can be ensured under convenient working conditions. No less important from the point of view of health and productivity is attention to all details which make for the comfort of the animals. Lastly the feeding arrangements should ensure to each cow her full ration and a supply of clean drinking water.

The type of accommodation provided in any particular instance is governed by such factors as the climatic conditions of the region, the nature of the soil on the farm, the total acreage and the proportion of arable to pasture, the intensity of stocking, and the labour available. In its turn, the accommodation must be appropriate to the type of herd management, and although there are wide variations as to detail three main systems* under which milk production is carried on in Great Britain to-day may be distinguished for descriptive purposes. These are —

(i) the *Cowhouse System* in which the cows are housed and milked in the same building.

(ii) the *Milking House* or *Milking Parlour System*, in which the cows are housed in cowsheds cattle yards or other available buildings but are milked in relays in a special milking house adjoining the dairy and

(iii) the *Open Air* or *Bail System* in which no housing is provided, the cows living continuously in the fields where they are milked by machine in a movable milking unit or bail.

Of these three systems of herd management, the Cowhouse with its all purpose building in which the cows are housed fed and milked is the one most widely followed, and it may be said to be the traditional system of dairying throughout the country. Its adoption, without doubt has been dictated by the prevailing climatic conditions of Great Britain in winter which are wet rather than dry, although temperatures are rarely so excessively low as to prevent cattle being put out-of-doors at any time.

The Milking House System is a comparatively recent development which has arisen partly in response to the emphasis now placed on hygienic methods of milk production, and partly as a result of the many previously arable farms which have been turned over of dairying in recent years to meet the ever increasing demand for milk for human

consumption. This system is capable of wide application wherever existing buildings are unsuitable for milk production, and where their adaptation would be too expensive or other wise impracticable.

The Open-Air System has been adopted in certain districts where climatic and soil conditions allow of the cows living and being milked in the fields either throughout the whole year or during the summer months only. The production of "clean" milk under such conditions is not easy, but the advantages claimed for the system are that the health of the cattle is better than under indoor systems, the capital and running costs are lower and the daily moving of the bail solves the problem of drainage and manure disposal.

LEGISLATION RELATING TO COWSHEDS.

Milk and Dairies Regulations, 1949. These regulations, made under the Food and Drugs Act, 1938, as amended by the Food and Drugs (Milk and Dairies) Act, 1944, determine the conditions under which milk for human consumption may be produced or stored in England and Wales.

Registration. Article 6 of the Regulations provides that the Minister of Agriculture and Fisheries shall keep a register of all persons carrying on the trade of dairy farmer, and of all dairy farms; any person who wishes to be registered as a dairy farmer or to register any premises as a dairy farm, shall make application in writing to the Minister of Agriculture and Fisheries.

General provisions relating to buildings and water supplies (Part V). This part of the Regulations deals with the necessary structural features of premises used for the production and storage of milk. The Regulations do not lay down precise dimensions and it is possible for cowsheds or milking accommodation of widely different types to fulfil the statutory requirements, provided they are so constructed and arranged to obtain the necessary light and ventilation and provided that cleanliness in milking operations can be readily maintained.

Ventilation and Lighting. Article 11 requires that a milking house or milk room shall be provided (*a*) "with a *sufficient number of openings suitably placed* and so used as to secure that the air therein is kept in a fresh and wholesome condition" and (*b*) "with such windows or such means of artificial lighting as are necessary to enable the milking of cows and any other process connected with milk to be conducted in a good and proper light."

In addition any building other than a milking house which is used for housing cows must be provided with light and ventilation adequate for the maintenance of the health of the cows.

Water Supply. Article 12 (1) "All registered premises shall be provided with a supply of water suitable and sufficient for the requirements of these regulations"; (3) "The water supply used for watering cows shall, *as far as is reasonably possible*, be protected against contamination caused by the drainage of foul water or otherwise."

Construction and cleanliness of premises. Article 13 "No occupier of any building, part of a building or shed shall use it as a milking house unless:—

(*a*) those parts of the surface of the floor liable to soiling by cows are impervious and constructed of such material and in such manner as to render it practicable to remove any liquid matter which may fall thereon and to prevent, as far as it is reasonably practicable, the soiling of the cows:•

—V.H. 15

(b) the floor is sloped and provided with gutters or channels of some impervious material as to ensure that any liquid matter which falls on the floor, or in the gutters or channels is thereby conveyed to a suitable drain outside the building and thence to a suitable place for disposal, but nothing in this regulation shall be deemed to prohibit the practice of providing for the absorption of such liquid matter into some removable material which is afterwards disposed of outside the building

(c) those parts of the surface of any walls liable to soiling or infection by cows are impervious and capable of being readily cleansed "

Requirements (a) and (c) do not apply to a movable milking shed, "but that shed shall be moved with sufficient frequency to avoid contamination of the milk."

There are similar provisions in regard to the nature of the flooring and drainage of dairies and milk rooms and parts of the walls liable to splashing by milk must be smooth and impervious   Such floors and walls must be wahsed down at least once a day

The approaches to all cowsheds, milking houses and milk rooms must be kept free from any accumulation of dung or offensive matter

Article 21 states that ' Milk shall not be handled, processed or stored in any place where it is liable to become contaminated or infected "   There follows a list of places in which handling and storage of milk are prohibited

Article 22 requires that adequate washing facilities for the milkers and all persons having access to the milk, shall be provided on the premises

Milk and Dairies (Scotland) Act, 1914   This Act required local authorities to make by laws providing *inter alia* ' for prescribing and regulating the structure, lighting ventilation (including air and floor space) cleansing, drainage, washing, and scalding facilities, and water supplies of dairies and their appurtenants "   It was not, however, until 1926 that the then Scottish Board of Health issued *Model Dairy By Laws* specifying the manner of laying down structural standards for dairy buildings   Following on this, local authorities enacted by laws within the framework suggested by the Board of Health, and these at present govern the general structure of dairy buildings   In view of the wide diversity in the standards set by different local authorities, it has recently been recommended "that the dairy bylaws so far as they relate to buildings be made uniform over the whole area of Scotland, and that provision be made for referring problems arising out of the application of such by laws to the Secretary of State for Scotland "*

THE COWHOUSE SYSTEM

The planning of a cowhouse in which cows are to be milked throughout the year and, in addition, housed and fed during the winter months must be given careful consideration, since the details of its layout, construction, and fixed equipment have important repercussions on the health of the animals, hygienic quality of the milk, and working costs and labour, as well as on the expense of initial construction and of subsequent upkeep   The cowhouse will form an integral unit of the farmstead—on most dairy farms the principal unit—and it is there-

fore important that it should be sited so as to give easy approach to a roadway and to the pastures, and convenient access to the dairy and foodstores. (See Arrangement of Buildings, p. 166.) A plentiful supply of pure water must be regarded as an essential for milk production, and is a matter which must receive the fullest attention when selecting a site for, and in the installation of the fittings of, both the cowshed and dairy. Where possible, the site selected should be somewhat higher in relation to its surroundings so as to give a convenient fall for drainage and an easy gradient for the carting of manure to the fields.

In order to reduce the initial building costs to a minimum and also to economise in working costs, it is a common practice to accommodate the whole milking herd in one building. The housing of large numbers of cows in an unpartitioned building has, however, from the hygienic standpoint the distinct drawback that diseases such as tuberculosis and air-borne infections may show a tendency to spread somewhat more readily through the stock, and especially to heifers in their first year in the milking herd. This is particularly liable to happen where the ventilation and general construction of the building are not of a high standard. For general health reasons, and also for the easier application of control measures against infectious diseases, therefore, it is desirable to split up exceptionally large herds into self-contained housing units with not more than about 50 animals in each, rather than to accommodate a larger number than this in one house. In any case, it is always a good practice to adopt some form of segregation with (a) first-calf heifers and (b) cows known or suspected to be affected with any form of contagious disease, e.g. contagious streptococcal mastitis, where propinquity in the cowshed is likely to favour its dissemination to non-affected animals.

Separate accommodation in the form of outside isolation boxes should always be available for parturient cows, and also for any sick animal, whether suffering from an infectious disease or not.

The health of the herd and cleanliness in the handling of the milk are two of the primary considerations in the planning and construction of cowhouses, and these requirements must always be secured if at all possible with a minimum of personnel and effort. It is well to remember, too, that no amount of expenditure on buildings can eliminate the necessity for scrupulous and unremitting care on the part of the staff.

Some of the essential points which must be studied in connection with the planning and construction of cowhouses are :—Suitability of site ; sufficient cubic space to allow of air change without "draught" ; a proper proportion between floor space and total cubic space ;

efficient ventilation and lighting ; the general arrangement of the cows in the building ; details concerning the stalls and feeding appliances, and construction of the building so that cleansing is easily carried out, and so that the labour of tending the animals is reduced to the minimum. Questions relating to the general construction, cubic air
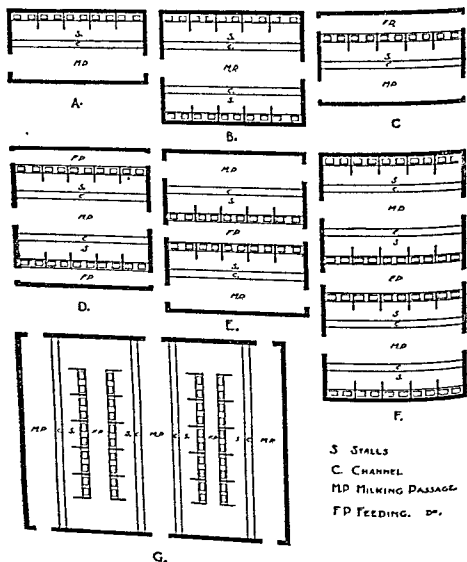
Fig. 67.—Alternative interior layouts for cowhouses.

space, ventilation and lighting, and external drainage of buildings have already been considered in previous sections of this book and need not be dealt with again here, except in so far as any point specific to cowhouses may be at issue.

Interior Layout. The standings in cowhouses may be arranged either in a single or in double rows. Where it is proposed to keep more than 16 to 20 cows, or where there is the possibility of the herd being increased, the double-range cowhouse is to be preferred on the grounds of convenience, saving of labour, and economy in both floor space and building costs. Double-range cowhouses should always have central gangways ; whether feeding passages along the side walls be adopted or not is probably a matter of individual preference. With a central gangway and the two rows of cows facing outwards, the heads of the cows are kept near the fresh air inlets in the side walls, the dung is confined to one passage and labour can be saved by using a cart or other mechanical means for its removal ; the cows can be tied up more readily; and milking can be supervised more effectively.

The diagrams A to G show the more common plans adopted in the internal layout of cowhouses.

In the single range cowhouse A and its double-range counterpart B, the cows stand facing the wall against which are placed the food-troughs. In C and D a feeding passage or alleyway is interposed between the cows' heads and the facing wall. In E, a double-range byre, the cows stand facing inwards with a feeding passage between, and a separate milking passage behind each row of cows. A byre of the type F is designed to hold four rows of cows under one roof and is a combination of D and E. In G the animals are arranged in transverse rows across the building.

Types A, B, C and D have no objectionable features, and all of them are in common use. E, F and G illustrate unsatisfactory layouts, and should not be adopted. Animals should never be placed so that they stand facing each other as there is more risk of respiratory infections being spread from one to the other, and also because the satisfactory ventilation of such a building is more difficult. Animals should face the air inlets in the walls so as to get the maximum benefit of the fresh incoming air. F and G are particularly bad arrangements as with either it is very difficult to secure proper air circulation within the building.

Internal Dimensions of Cowhouses. *Width.*—In the case of a building intended for the housing as well as for the milking of cows of average size, such as Dairy Shorthorns, and on the assumption that central ties and wide continuous mangers with low fronts are to be installed, the minimum internal dimensions for a single-range layout should be as follows : gangway 4 ft. ; dung channel 3 ft. ; standing 5 ft. ; manger 3 ft. ; feeding passage (optional) 3 ft. : Total width of building 15 ft. (or 18 ft.).

RIDGE VENT   ROOF LIGHTS ON THE NORTH OR EAST SIDE

8'0" MIN

3'0"   7'6"   6'0"   3'0"   3'0"   7'6"   3'0"

1V DPC   6'   6"   6'   2'   2'   6'   6"   NLET VENT DPC

CROSS SECTION

END ELEVATION
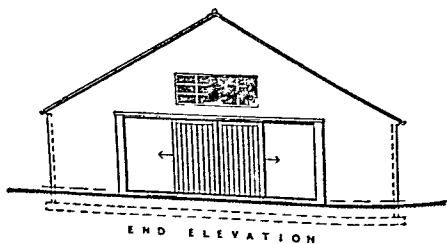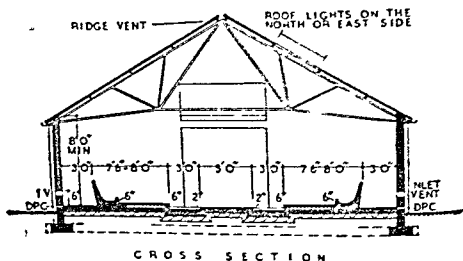
SCALE OF FEET
5 4 3 2 1 0   5   10   15   20

FIG 68.—Double range cowshed with central ties, continuous mangers and feeding passages.

RIDGE VENT — — — — — — — — — — ROOF LIGHTS

SIDE TIES
INLET VENT
MANGERS

INSULATION

DOOR 4'0" WIDE
IN 2 HALVES

CAUSEWAY

DPC

HARDCORE CONCRETE

SECTION

PART ELEVATION

MANGERS

FOOD

12'0"

7'0"   7'0"   7'0" DAIRY

STANDING   7'6"

1½"

DUNG
CHANNEL
(FALL HALF INCH PER FEET)

3'0"

14'6"

GANGWAY

4'0"

WATER

DOUBLE
GULLEY

CAUSEWAY
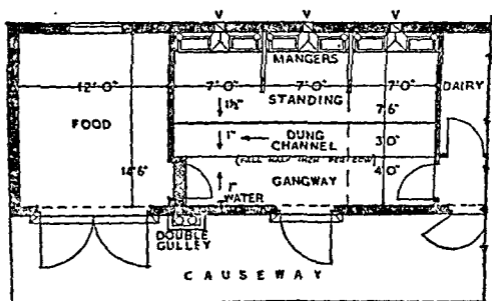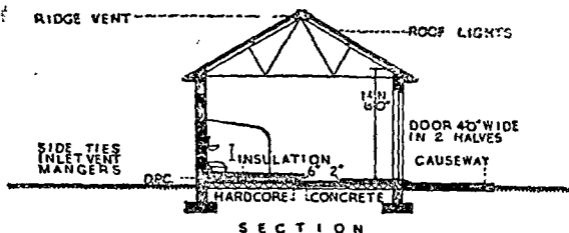
SCALE 5 4 3 2 1 0   5   10   15   20 FEET

Fig. 69.—Single range cowshed with side ties, individual mangers and no feeding passage.

Similar minimum dimensions apply to a double-range cowhouse (Fig. 68) of the same type, except that the central gangway should be 5 ft wide Total width of building 27 ft (or 33 ft.)

In a cowhouse with side ties and low, individual narrow mangers, the distance from the wall or feeding passage to the dung channel should not exceed 7 ft 6 in With mangers up to 2 ft wide, the point of tying should be 2 ft from the wall or feeding passage Wider and continuous mangers up to 2 ft. 6 in may be used but with these the point of tying must be in line with the front kerb of the manger Other dimensions are the same as for central tying. Total width of building 14 ft. 6 in. (or 17 ft 6 in) for single range (Fig. 69), 26 ft (or 32 ft) for double range

Length—The length of a cowhouse will depend on the number of standings it contains, each of which should allow a width of 3 ft 6 in for the average Shorthorn cow, or for smaller breeds 3 ft 3 in On this basis 6 ft 6 in or 7 ft will normally be required for each double stall For a single stall 4 ft should be allowed so as to give room for cleaning and milking operations

Height—The height of the inside of the wall of a cowhouse should not exceed 8 ft, since excessive height in a building leads to faulty ventilation and the possibility of down draughts Height to ridge should be 15 ft. or 16 ft

Walls. The internal surfaces of cowhouse walls should have a smooth, hard finish of cement rendering, or be faced with glazed tiles or bricks to a height of at least 4 ft. 6 in , above this they should be smooth finished in cement rendering to prevent lodgment of dirt and dust. All corners and angles in the cowhouse should be filled in with a fillet of cement

Doors. In a single range cowhouse the doorway by which the cows enter and leave the building should be 7 ft high and a clear 4 in width. A door of the divided type, the lower portion being 4 ft. high, made to open outwards, is recommended. It is important that doors of this type be so hung that they l e flat against the external wall when fully open, so that there is no interference with the outward or inward passage of the animals

For a double range cowhouse the doorway should be a clear 8 to 9 ft wide. Double hung or sliding doors may be used , if the latter they should be on the inside of the building as this gives better protection to the sliding railway mechanism from the weather

The methods of ventilating and lighting cowhouses have already been dealt with in Section on "Air, Ventilation and Lighting," to which reference should be made

Feeding Passages. Some difference of opinion exists concerning the advisability of having a feeding passage in front of the cows, or whether it is better to dispense with the passage so that the cows stand close to the facing wall. A feeding passage is useful when yokes or similar ties are used as it facilitates feeding, particularly of roots and bulky fodder, which can be done more easily from a front passage than when the attendant has to push his way to the trough between each pair of cows. One end of the passage should communicate directly with the food-mixing room, so as to allow a trolley to be run straight into the passage in front of the cows. Where this layout is adopted, the width of the passage need not be more than 3 ft. It has been noted that the wider a feeding passage is made, the greater is the temptation of herdsmen to use it for storing hay and other feeding stuffs instead of restricting its use to its more legitimate purpose. Instances, too, are not unknown where the feeding passage has been used as a pen for calves, a practice which is obviously unsound, and open to the gravest objection.

There can be little doubt that feeding passages make for the better observation of, and individual attention to, the cows at all times. Houses without feeding passages, however, are narrower, less costly in erection, and may be more readily adapted for other uses, should the need arise. In some parts of the country, particularly in Scotland, it must be noted that there is a distinct prejudice against feeding passages, but whether this is well-founded in fact it is not easy to say. Many experienced dairymen base their objection to it on the affirmation that instead of reducing the general labour in a cowshed, the installation of a feeding passage actually increases it, but such reasoning is not easy to follow.

Standings. The actual area on which a cow stands and lies should be limited in length so as to prevent the dropping of faeces and urine on the floor in such a position that the cow would lie on these excreta, thereby soiling the quarters and udder. It is true that this limitation of space may restrict the animal's backward movement, but it is an essential aid in the production of clean milk.

If the standing is too big in either breadth or length its whole surface tends to become covered with dung because of the wide range of movement in all directions which the animal is allowed. When a standing is properly proportioned, most of the excreta should fall into the dung channel behind the cows. If the standings are so constructed that cows are continually soiling their udders with manure, the labour involved in keeping them clean is so great that it is seldom satisfactorily done.

Should the stalls be too short the cows stand with their hind feet perpetually in the dung channel, to the marked detriment of the hoofs and fetlocks, and to the obvious discomfort of the beasts both when standing or lying

The length of the standing should be such that when the cow is standing in a natural manner the heels of her hind legs are just at the border of the channel at the rear of the standing It is, therefore, obvious that the length must vary according to the size of the cow For small breeds of cows, such as Jerseys and Kerrys, Spier* recommended a length of 6 feet 10 inches to 7 feet from the facing wall to the gutter edge, for medium size cows, such as Ayrshires, 7 feet to 7 feet 3 inches, and for Shorthorns a length of 7 feet 6 inches These dimensions have been found to be generally suitable where low, narrow, individual mangers are installed and side ties are adopted

When there is a feeding passage in front of the cows, measurements may be made from the manger, in which case the length of standing may be from 4 feet 9 inches to 5 feet 3 inches according to the size of the cows to be housed A length of 5 feet from the front of the manger has been found suitable for average sized Shorthorn cows when central ties and wide continuous mangers are installed

Where cows of markedly different sizes are included in the same herd, some variation in the lengths of the standings can be arranged by constructing the back step out of parallel with the manger front, thus giving standings which taper from one end of the building to the other ; the necessary adjustment is taken up in the dung channel, thereby retaining a constant width for the milking passage

The common custom is to keep cows in pairs in double stalls This effects a saving of labour in milking and tending the animals, and reduces the cost of construction The breadth of the stalls is an important consideration If they are too broad cows can turn sideways and foul the standing with faeces, and if they are too narrow the cows, in double stalls, tread on each other's legs and udders Many cases of mastitis are caused by injuries from treads

The width for double stalls may vary from 6 feet 6 inches for small animals to 7 feet 6 inches for the largest For single stalls a width of 4 feet, and for double stalls a width of 7 feet, will be found suitable for most cattle

Flooring of the Standing The flooring of standings should be finished with some impervious material that is easily kept clean and is not slippery, and which will remain reasonably warm and dry The surface should be laid with a uniform fall of 1 to 1½ inches from

manger to dung channel. Cement concrete, although it has a distinct tendency to coldness, is otherwise generally satisfactory ; it is relatively cheap, easily laid and durable. If allowed to become dirty or if it has been finished with a smooth surface, however, it may be slippery and dangerous. The cement flooring will be kept drier, and therefore warmer, if there is a good bed of loosely packed hardcore of coarse rubble underlying the 4 inch layer of concrete, or if hollow building bricks or drain pipes are laid on a suitable foundation and covered over with $1\frac{1}{2}$ to 2 inches of fine cement concrete. To give a good foothold the finished surface should be roughened with a stiff broom or straight edge, or sprinkled with powdered carborundum.

Compositions of cork, rubber, and asphalt, either in the form of bricks or laid *in situ* have been tried for the floors of standings, but whilst they may present advantages in the form of resilience and warmth, no material of this sort has yet been devised which is entirely satisfactory from the point of view of durability and economy.

Gangways and Milking Passages. A wide passage behind the cows is advisable for several reasons. The cows when entering or leaving the shed have room to turn with greater comfort and safety than when the space is restricted, and there is thus less likelihood of animals slipping and falling ; if the rear passage is narrow, the hind quarters of the cows are very often in shadow ; the wider the passage, whatever the method of lighting may be, the more clearly will the udders and hind quarters be lighted up ; with a wide passage, there is less risk of dung and urine being splashed into the milk pails when these are being carried up and down the byre, or are left standing in the centre of the passage during milking ; furthermore, if the passage behind the cows is very narrow the wall will commonly be found to be splashed with dung, and the space will be too cramped for the staff to carry out their work efficiently.

The milking passage in a single-range cowhouse should be at least 4 feet wide, with a fall of 1 inch towards the dung channel. In the milk. No form of underground drainage is permissible in the case of a double-range building there should be a central passage, slightly cambered and not less than 5 feet wide. The flooring of the passage should be of cement concrete, finished with a rough, non-slipping surface. Where the back wall joins the floor surface in a single-range cowshed the angle should be filled in with a fillet of cement, all the corners being rounded out ; this important detail is usually omitted.

Interior Drainage of the Cowhouse. The interior drainage of cowhouses is of great importance because of its close bearing on the

cleanliness of the cows and, consequently, on the hygienic quality of houses   The drain, or dung channel, must be an open channel behind the standings running the length of the building, and discharging into an open gulley trap placed outside the building.   The latter is connected to a suitable drain or other place of disposal which, in the interest of herd health, must not be near any ditch or stream or other source of water supply to which cows or other farm stock have access, or from which water supplies for the cowshed dairy, etc , may be drawn

The dung channel must be wide enough to hold dung and such bedding as may get into it without becoming overloaded and blocked   Suitable dimensions are—3 feet wide with a cross fall of 1 inch away from standing, and a fall of ½ inch per cow throughout its length
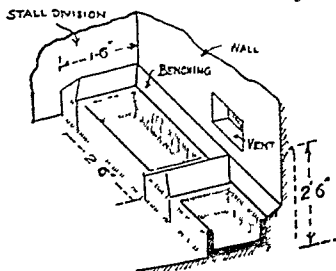
Fig 70 —Individual glazed stoneware manger set and perched in cement concrete showing by dotted lines the dwarf wall which is necessary when a feeding passage is provided

which is usually provided by the general slope of the floor, thus maintaining a uniform depth of channel for its entire length   It may help to facilitate the flow of liquid drainage if a smooth finish is given to the surface of the concrete in the dung channel for a width of 4 inches from the edge of the passage   Cross channels should be avoided unless the dung channel is longer than about 70 feet   Where they are necessary, they should be about 12 inches wide, be covered with movable gratings and lead straight through the wall to discharge into an out-side trapped gully placed as near the external wall as possible   The longitudinal gradients of the dung channel should be arranged to carry the liquid toward the cross channels

There has been much discussion concerning the depth of the dung channel   Whilst most people agree that the channel should be fairly deep, 6 to 8 inches at the side next to the standing, there apparently

considerable difference of opinion regarding the best depth at the passage side. It is thought by many that a channel which is shallow at the passage side enables a cow to step into it and then on to the standing without difficulty, whereas if it is deep (6 or 7 inches) cows may attempt to jump the channel and thus may possibly injure themselves. On the other hand, it is claimed that a high back-step to the channel reduces the amount of dung splashing out on to the milking passage. Experience would appear to show that a vertical step of not more than two inches from the dung channel to the milking passage is always to be preferred to one deeper than this. The edges of the steps at both sides of the dung channel should be only very slightly eased from the sharp edge—never bull-nosed or rounded off edges which predispose to slipping.

In some districts the step from dung channel to the milking passage is omitted altogether. In such a case, drainage of the liquid excreta and washing water is secured by sloping the gangway towards a shallow gutter, 6 inches wide and $1\frac{1}{2}$ inches deep at its lowest point ; the gutter surface is finished smooth to facilitate the flow of liquids. This modification may be profitably adopted in the adaptation of existing buildings where the space behind the standings, either in single or double-range cowsheds; is too narrow to allow a 3 feet wide dung channel in addition to a 4 feet or 5 feet wide passage-way respectively.

Mangers. Mangers should be made of some hard, impervious, and acid- and alkali-resisting material, and so designed that they may be easily cleaned. Timber is not a suitable material to employ for these purposes. Two main types of manger are now commonly used, *viz.,* (i) individual glazed stoneware mangers and (ii) continuous concrete mangers with high backs.

· *Individual mangers* (Fig. 70) need not be more than 2 ft. 6 in. long, 18 in. wide and 8 in. deep (*external measurements*). Each manger should be set in concrete, with its base on the level of the standing, and finished with a raised concrete benching at the back and sides. If there is a feeding passage, the manger should be backed by a dwarf concrete wall to a height of 2 ft. 6 in. from the floor of the feeding passage ; this wall is necessary to prevent cows nosing their food over the back of the manger. In addition, with this type of manger two or three horizontal rails may be fitted above the dwarf wall in order to prevent cows attempting to move forward into the feeding passage. The supply pipe for pressure feed water bowls may be utilised as one of the rails. The individual manger has the definite objection that its design and method of construction do not make for

easy cleaning of the trough. This becomes dirty very quickly, especially when sloppy fermentable food, wet brewers' grains, or silage are being fed; in such circumstances there is need for frequent and thorough cleaning, but since this is such a laborious and difficult matter with individual mangers, cleaning is seldom done effectively.

Continuous mangers (Fig. 71) are made of concrete or stoneware and are now usually fitted with concrete or metal divisions to make a section for each cow or each pair of cows. Glazed-ware manger linings are now available; these are laid continuously in concrete, care being taken to see that all jointings are accurate. A lining of this kind is
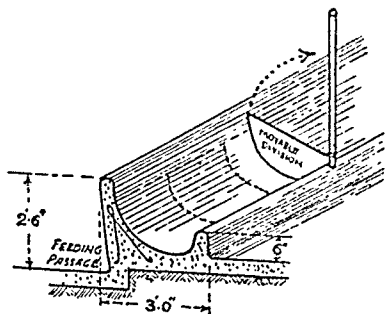
Fig. 71.— Continuous manger of reinforced concrete rendered smooth internally with acid-resisting cement or, alternatively, lined with glazed stoneware units as shown by dotted lines. A movable manger division is also indicated in the figure.

far more satisfactory than a concrete finish, which becomes rough and pitted after some years' use. Linings are obtainable in half-round sections, or shaped similarly to the standard type of manger, and may be built in with concrete smooth finished in the normal way. Where cows are secured by central ties, the manger should be 3 ft. wide; if side ties are used, the width may vary between 1 ft. 6 in. and 2 ft. 6 in. A convenient height for the back is 2 ft. 6 in. above the feeding passage; higher than this makes the filling of food into the manger less easily done by the man of average height. The height of the front kerb above the standing should never exceed 6 in., otherwise cows may have some difficulty in lying down and in rising. The lowest point in the manger should be 1½ or 2 in. above the level of the standing, and not more than 9 in. from the front kerb; these dimensions permit the

cow to reach food in any part of the manger without undue forward movement or straining. The back of the manger next to the feeding passage may be constructed so that it slopes slightly and progressively outwards from the floor of the passage to the top of the manger wall ; this gives toe-space to a person filling the manger. Fixed concrete or movable metal divisions should be fitted to divide the manger into sections corresponding to each cow ; this ensures that every animal gets its full ration of food, without any fear of pilfering by neighbouring cows. The continuous manger with removable metal partitions possesses the great advantage that it can be easily and regularly cleaned by flushing with water from one end to the other, a consideration which is not inconsequent, having regard to the numerous other tasks which must be performed in connection with dairying and milk production. It has been affirmed that with the continuous manger without divisions there is a greater risk of spreading tuberculosis and other respiratory infections ; this, however, is merely an assumption with little foundation in established fact. It would seem rather that the system of housing dairy cattle with its close propinquity of the animals without any method of effectively separating one from the other, affords so great opportunities and so diverse routes for the spread of infectious disease, that to determine whether one type of fitment was more dangerous in spreading infection than another would be almost impossible.

All food, including hay, should be fed in the mangers. Hay racks are quite unnecessary in dairy cowhouses, and in carrying out adaptations or improvements to old buildings they should always be removed.

Stall Divisions. Partitions between stalls are installed for the purpose of restricting the sideward movement of cows and for preventing them from lying across the stalls. Stalls may be single or double, the latter type being recommended in preference to the former. The stall division should not be longer than 3 ft. from the point of tying.

Two types of division are suitable for dairy cowhouses :—

(i) Solid divisions of reinforced cement concrete, built *in situ* or pre-cast, and finished with a smooth, hard surface to enable easy cleaning: the divisions should be about $2\frac{1}{2}$ in. thick, 4 ft. high at the head, sloping to 3 ft. 6 in. at the rear. If partitions are too long or too high, the cows may have difficulty in entering and leaving the stalls. (Side ties are used with this type of division.)

(ii) Simple tubular metal divisions, usually galvanised iron, for use with central ties. From the hygienic standpoint, this type is probably the more satisfactory in that it allows of a freer circulation of air and facilitates the cleansing of the standings.
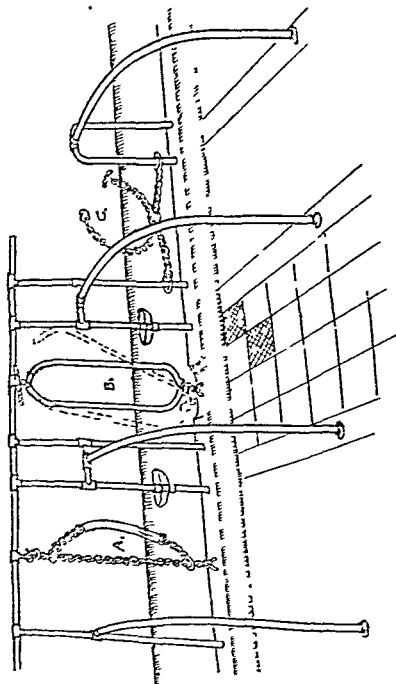
Fig 72 —Types of tubular metal stall divisions and alternative pattern ties   A Dutch Chain   B   Metal yoke with adjustable herd for shortening or lengthening the stranding   C. Double chain,

Securing the Cows. For reasons already given cows have to be confined to a definite and circumscribed area. It is therefore necessary that they should be so tied as to limit their movement. The common practice in cowhouses where solid partitions are in use is to tie the cows round the neck by means of a chain or rope, the other end of which is secured to a ring that has perpendicular play up and down a rod bolted to the side of the solid stall division. Some types are provided with a means of adjustment to suit the length of the cow. All should be fitted with a device to ensure quick release.

Where tubular metal divisions are installed, central tying is adopted, either in the form of a double chain, all-metal yoke or the Dutch chain tie (see Fig. 72). All types restrain the movement of the cows to a much greater degree than side tying.

Food and Manure Carriers. In large byres a great saving of labour is gained by using carriers for the soiled litter and dung and for the food. These may run on tracks or on overhead rails, one set going direct to the dung pit and the other to the food preparation house. The latter should be attached to, or situated within easy reach of, the cowhouse.

Water Supply to Cowhouses and Dairies. On an average, the *minimum* daily requirement of water for stock drinking, cooling purposes in the dairy, washing cows and cowshed prior to milking operations, and the cleansing of milking utensils, etc. may be put at about 30 gallons per cow. Water should be laid on to the cowhouse, cooling room, and the washing and sterilizing room, the taps being located at convenient points. The latter should have hose-pipe connections in the cowhouse ; similar fittings are also useful in the dairy, etc. for facilitating the cleansing of floors. Hand basins should always be available to the milking staff for personal washing purposes.

If a private source of water supply is limited in quantity, or if the cost of the quantity drawn from a public main is a consideration, it is an economy if water that has been used for milk cooling purposes can be made available for further use in the washing of the cows and cowhouse and for watering the stock. Fig. 73 illustrates the general method by which this may be done in the case of a supply obtained from a well or similar source.

Method of Watering Stock in Cowhouses. Dairy cows should be allowed constant access to water ; the provision of some form of automatic water supply in cowhouses is therefore essential. This is secured by one or other of the various systems of automatically filled

drinking-bowls, in which the water is supplied independently to each cow or each pair of cows. There are two systems of automatic water supply which have proved satisfactory in practice :—

(i) that in which the drinking bowls have a pressure feed and
(ii) that where the bowls are on a gravity feed with a non-return valve.

Pressure-type Drinking Bowls.—The principle adopted is to fit the inlet-pipe of each bowl with a spring valve which can be operated at will by the animal by depressing a hinged lever. This allows water to
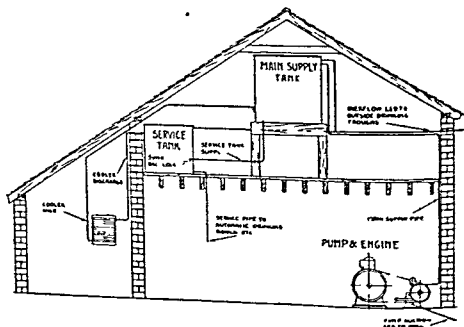
Fig 73 —A water installation designed for maximum economy in the use of the supply. Water from cooler is used for drinking and washing purposes.

flow into the bowl, the flow ceasing as soon as the pressure on the lever is released. In this system the water-supply may be taken direct from the main, provided the pressure in the supply pipes does not exceed 15 to 20 lb per square inch ; a higher pressure will cause "hammering" of the valve, which is governed by an extension coil-spring. Consequently, where a high pressure main supplies a cowhouse, some method of reducing the water pressure must be adopted. This is usually effected by feeding the bowls from a large service tank fixed about 15 feet above floor level, this tank being in turn supplied from the main through a ball-cock tap.

There are numerous types of pressure bowl on the market, but according to one authority* the design of many is faulty in that it

* Fowler A. B (1933) "The Construction and Equipment of Cattle Byres, Part II. Automatic Drinking Bowls" *Scottish J Agri*

does not permit free movement of the lower jaw while the animal is drinking. In this connection it should be remembered that the cow during drinking is constantly moving her lower jaw as she swallows the water. To allow this natural movement, a bowl which is elongated in shape, instead of circular, has been recommended. The hinged lever of this bowl is practically vertical so that the animal in drinking can use her nose pad to operate the flow of water instead of her lower jaw, as is necessary with a horizontally placed lever. By this means the cow can exert a constant pressure on the lever, thus receiving a continuous supply of water, whilst at the same time retaining perfect freedom of lower jaw movement for swallowing.

Gravity-type Drinking Bowls.—In this system the inflow of water
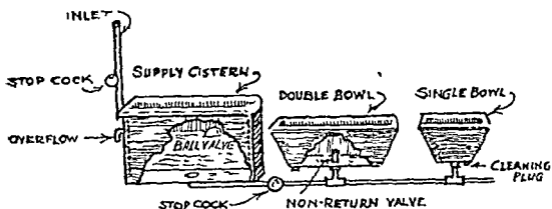
FIG. 74.—Gravity-type Drinking Bowls.

to the drinking bowls is controlled by a constant level water-cistern, which is fitted with a ball-cock control (see Fig. 74). From this cistern each individual bowl is supplied by a common pipe, the cistern being situated so that the level of the water in the bowls is maintained at the desired height. The cistern, which is connected to the main storage tank, should be fitted with an emergency overflow pipe to prevent the possibility of the water in the bowls overflowing into the manger.

Gravity-type bowls in which the water is fed directly into the bottom of the bowl from the common supply pipe possess the great disadvantage that it is extremely difficult to keep the water in the bowls clean and wholesome, since particles of food, such as fine meal, inevitably dropped into the bowls by the cows are liable to settle in, and even block, the common feed pipe, thus giving rise to contamination of the water. A more recent development has overcome, if not wholly at least partially, this defect. This consists in the insertion of a non-return valve in each incoming pipe where it enters the bowl;

the valve should be so fitted that the water enters, not at the lowest point of the bowl, but at 1 to 1½ ins from the bottom, thus allowing a space for sediment to settle and thereby preventing solid particles from getting into the valve and interfering with its closure   By this means it is claimed that the water in the bowl is automatically sealed off when the latter is filled, and thus back-flow from one bowl to another, which would otherwise occur when the water-level in any bowl is lowered by drinking, is prevented

Position of Drinking Bowls—The position in which drinking bowls should be fitted must be considered in relation to the type of stall division, the method of tying the cows, and the form of manger In cowhouses with solid stall divisions, side ties and narrow mangers, a separate bowl for each cow is desirable   The bowls are placed at the back of the manger either in the angle formed by the facing wall and the stall division, or centrally between each pair of cows in a double standing, the bowls being 10 in to 12 in apart   Bowls in the former of these positions, and when side ties are used, are said to impede the rising of the cow, and for this reason the central position is probably the more desirable   The height of the bowl should be 2 ft to 2 ft 6 in above the level of the standing floor

Where yoke or similar close ties and the wide continuous type of manger are adopted the bowls should be at the front, not the back, of the manger , they are usually fitted to the tie standards on the stand ing side with the top of the bowl about 2 ft above the manger front Separate bowls, placed between the two cows in the same stall, are to be preferred from the disease dissemination point of view to one bowl (single or twin) serving two cows

Calving and Isolation Boxes, etc   Special accommodation in the form of loose-boxes should be provided for parturient cows   The practice of allowing cows to calve in the milking cowshed is most objectionable both in regard to "clean ' milk production and in connection with the dissemination of contagious bovine abortion, and possibly also other diseases

It is necessary also to provide on every dairy farm adequate quarters for the efficient isolation of cows suffering from infectious diseases, or for bought in stock before introduction into the herd Loose boxes are very suitable for these purposes , they should be some distance away from the cowhouse and from buildings housing calves and other young bovine stock, be self-contained, have separate con nection to the drainage disposal system, and be constructed so that they can be easily cleaned and disinfected   In general construction they will resemble the type of loose-box described for horses (page 203)

It is not uncommon to find a loose-box actually in the cow-shed or leading directly from it. This position for a loose-box intended for isolation purposes is obviously wrong, but it is often very useful to have a loose-box so situated, provided it is used only for housing animals which are lame, or have difficulty in rising, or are suffering from some minor upset, and whose milk is still being included in the supply from the farm.

The Dairy. The size and construction of the dairy will be determined by several factors of which the most important will be the quantity of milk produced and whether it is bottled on the farm or must be stored for any length of time prior to delivery (Fig. 75).

In any case two separate rooms should be provided, one in which the milk is cooled and bulked, or placed in bottles or churns, and another in which the churns, etc., are cleaned and sterilized. The milk room must be near but not in direct communication with the cowshed. For convenience and for protection in wet weather, the approach to the milk room should be roofed where necessary. The manure pit should be placed as far away from the milk house as possible. It is necessary to keep the milk house cool, therefore it should, if possible, have a northerly aspect. Good ventilation and lighting are essential. The room must be constructed so that it can be easily cleaned ; to allow of this, the walls must be smooth, the lower part to a height of approximately 6 feet from the ground having a polished cement finish, or be faced with tiles or with enamelled bricks. The upper part of the walls should be limewashed or painted. A smooth impervious floor with good drainage to an outside drain is essential. There must not be any unnecessary ledges or corners in the room. All shelves should be of material that can be easily cleaned and should have a clearance of 2 inches from the wall. The room should be made fly-proof with wire gauze. This can be easily done as far as the windows and ventilators are concerned by fitting them with a gauze covered frame, but in the case of doors the procedure is not so simple. A satisfactory method is to have a double door, that is, one constructed in the usual way of wood, and on its inner side having another made of wire gauze supported by a skeleton of wood or metal. To this inner door must be attached a strong spring which ensures that it is continually closed except when someone is actually passing through. If such a method is employed the wooden door may be left open to assist ventilation when the weather is hot and flies numerous.

The milk room will contain the cooler and clean churns, and also any other equipment, such as bottling machines and separators. As it is advisable to reduce traffic in and out of this room as much as

FUEL

BOILER ROOM 6 x 3'6"

STER CHEST 3 x 3

POWER UNIT & VACUUM PUMP 6 x 5'

STEAMING STOOLS

CLUSTER RACK

WASH-TROUGHS

COLD   HOT

TABLE

WASHING & STERILISING ROOM 12' x 12

IN

CHURNS

OUT

RACK

COOLING ROOM 12' x 9'

DEADLIGHT

COOLER

N

CUPBOARD

MILK RECEIVING ROOM

TIP

LB

32'

12'

Feet 0   5   10 Feet
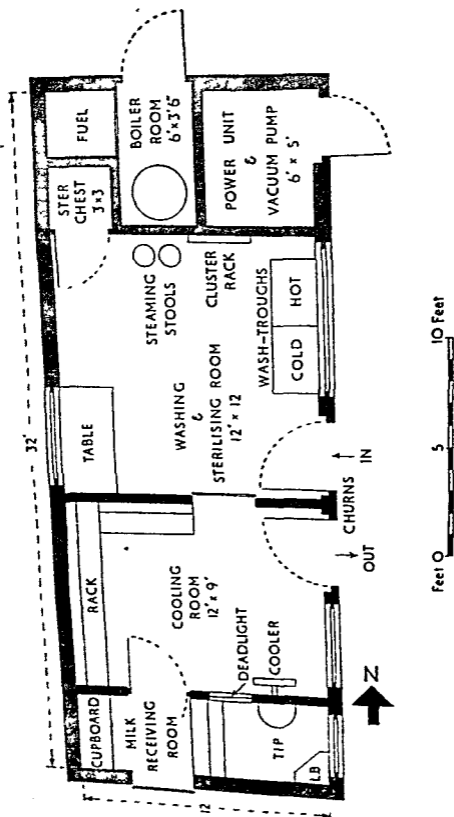
Fig. 75.—A Dairy for a Large Herd

possible, weighing and straining the milk should not be done in it, the strainer being fixed at a suitable height in a separate milk receiving room. After it has been strained the milk would then pass through the separating wall via a pipe to the cooler in the milk room. Both the strainer and the pipe should be removable for cleaning and sterilization.

Adjacent to the milk room, a washing and sterilizing room is necessary. In this room dirty churns, milking machine parts, bottles, etc., are received for washing and sterilization. It should be supplied with hot and cold water and steam, and the necessary cleansing and sterilizing appliances.

Finally there should be a separate house for the boiler when solid fuel is used. If a gas or electric sterilizer is installed, it may be placed in the washing and sterilizing room.

THE MILKING HOUSE OR MILKING PARLOUR SYSTEM

On many farms it has been found impossible for one reason or another to alter or adapt existing buildings for the production of milk in accordance with modern standards, although the buildings, after some slight adjustment, may be suitable for providing shelter for the dairy herd during the winter months. For example, on some arable farms where the farmstead may have been originally designed and used for bullock feeding, and where the buildings comprise covered or partly covered yards ("courts" in Scotland), the entire remodelling of the layout and animal accommodation in order to conform with the requirements for milk production would in most cases be too costly, and perhaps also inadvisable in view of the possibility of reversion to arable farming at some future date. In these and similar circumstances a solution to the problem has been found in the provision of a *special* milking house or parlour, relatively small in size and comparatively cheap to erect, which is devoted solely to the various procedures connected with the milking of cows. The existing buildings or yards on the farmstead can then be utilized for the *general* housing of the cows, thereby eliminating the necessity for extensive alterations, or alternatively the expense of erecting a new and up-to-date cowhouse of the type which has been described in the preceding pages.

There are other considerations, too, which favour a departure from the common cowhouse system under which the herd is both housed and milked in the one building. Thus in addition to the high initial cost of the modern cowhouse and its fittings, the difficulty of maintaining the high standard of cleanliness required for milk production in a building where the cows are also continuously housed and fed is great. Another aspect concerns the health and comfort of the cows; the confinement of animals for long periods without any adequate exercise

in a warm and humid atmosphere, such as is commonly found in cow-houses, is hardly conducive to the maintenance of an optimum standard of health. For these reasons, therefore, the provision of separate milking accommodation, and particularly when it is associated with the keeping of the cows in open, or in partially covered, yards, has been adopted in many instances through confidence in the intrinsic merits of this system, and not necessarily because a cowhouse of the usual type could not have been provided.

The main *advantages* claimed for the special milking house as compared with the cowhouse system may be summarized as follows :—

(i) The cost of erecting a new milking house, or the adaptation of an existing building to serve the same purpose, will usually be less than that for the remodelling of an existing cowhouse or for the erection of a new cowhouse.

(ii) The operations at milking-time can be supervised more readily by a responsible overseer

This ease of supervision is of great importance in the production of "clean" milk, and has also considerable relevance to the control of contagious streptococcal mastitis, in that the enforcement of methods for the detection of early udder disturbance is facilitated   Concentration of milking operations also allows of the more ready application of suitable hygienic measures for preventing the spread of udder infection through handling of the udder and teats at milking-time.

(iii) The keeping of the cows in yards enables the animals to get more fresh air and exercise, making them less susceptible to respiratory diseases.

(iv) The animals enjoy greater comfort, since they are not forced to lie on floors which are continuously wet from washing operations.

(v) Less water is needed for the hosing of standings and for washing cows prior to milking.

There is thus less effluent, and no special arrangements need be adopted for the separation of waste washing-water and liquid manure Where the cows are housed in yards the urine is conserved along with the dung and straw, which is then removed to the fields at convenient intervals

(vi) Yards are more convenient than cowhouse standings for the feeding of bulky fodder, roots, etc., since there is ample space for mangers and for easier access to them than is possible in a cowhouse

(vii) Since only concentrates are fed in the milking house, and

also because no bedding is ever brought in, its atmosphere is relatively free from dust and other particulate matter, and clean milk production is thereby facilitated.

Some of the *disadvantages* which have been advanced against the milking house system are :—

(i) Danger of bullying in the yards unless the "master" cows are separately accommodated, or dehorning is practised.

(ii) Difficulty of controlling individual rationing.

This objection is undoubtedly a real one as far as high-yielding cows are concerned. In the milking house system, hay, roots and other bulky foods are given in the buildings or yards housing the cows, or in the fields, the concentrate ration being fed in the milking stalls. The amount of time available for eating concentrates is a matter of great importance with high-yielding cows. With cows of average yields there should ordinarily be no difficulty, but with cows giving 1,200 gallons or more in a lactation, experience has shown that ample time for feeding, as well as close individual attention, is essential, and that, therefore, *any form of batch milking is unsuitable for such cows.* It may be reckoned that a cow requires about two minues to consume 1 lb. of concentrates. This may involve a period of 10-15 minutes, or even longer in indivudual cases, in the milking stall, according to the amount of milk being produced at the time by the cow. If this period is unduly shortened it is obvious that both the cow and her yield will suffer. *In many herds of high-yielding cows this difficulty is now* overcome by feeding the concentrates, as well as the bulky portion of the ration, in the yards. To facilitate rationing, yokes are provided at the mangers in the yards so that the cows may be fastened up for feeding.

(iii) Difficulty in controlling certain contagious diseases in yarded animals, *e.g.*, ringworm, Johne's disease, contagious abortion and some internal and external parasitic infestations.

No serious trouble need normally be anticipated from this source, however, provided the standard of general herd mangement is good, and due attention is paid to hygienic measures such as removal of the accumulated excreta and manure at regular intervals, treatment of woodwork in the hards with suitable disinfectant preparations, prompt removal of sick or infected animals, and effective quarantine of newly purchased animals before their admission to the herd.

(iv) Unless straw is available in large quantities for littering the yards they quickly become fouled and insanitary.

This objection is not usually a valid one in wheat-growing districts,.

but where oats is the chief, or only, corn crop, the oat-straw is frequently regarded as being more valuable for fodder than for bedding, with the consequence that there will be insufficient for use in cattle yards

General Outline of the System in Practice —The *Special accommodation* provided for milking operations may be either a new building specially designed for this purpose or an existing building which has been suitably modified The former may take the form of a comparatively small building of permanent construction, or it may be a lightly-built sectional shed which, whilst being relatively permanent in its location, can be taken down and re-erected elsewhere (The movable shed has the advantage that it can be put up as a tenant's fixture, in which case it is removable to another farm should the need ever arise) Where the adaptation of existing buildings is to be undertaken there will be considerable variation in the type of accommodation available and the detailed planning in each individual case must depend to a large extent upon circumstances and surroundings A point of considerable importance in the layout is that the dairy should always adjoin, or be in close proximity to, the milking house

For the *general housing* of the milking herd during the winter months, existing cowhouses or cattle yards may be utilised These must have adequate light, ventilation and drainage, and generally provide satisfactory living conditions for the maintenance of good health Separate accommodation is essential for parturient cows, whilst special provision must be made for the segregation of diseased or potentially infected animals Facilities must also be available for the prevention of bullying in the yards, and for the management of exceptionally high-yielding animals Small herds may be housed in a single enclosure, but for larger herds it is desirable to have separate yards or pens for every 10 to 15 cows, grouped according to yield and general convenience of management A yard area of 100 sq ft per head is recommended for the smaller breeds and for dehorned and polled cattle, and about 150 sq ft for the larger breeds with horns

An added facility where cattle are kept in yards is to have a crush for the purpose of carrying out tuberculin testing, blood sampling, and other veterinary operations necessitating the restraint of individual animals

Gates and passages should be arranged to secure an orderly procession of cows from the housing quarters to the milking house, and back again Generally speaking, it is best that the route of circulation should be kept as simple and direct as possible

Washing of the cows before milking may take place either in the milking stalls or, alternatively, in special washing stalls placed in a

row behind the milking stalls. The first of these arrangements is probably preferable, because with separate washing stalls a larger building and more fixed equipment is required. The movement forward of the cow after washing into the milking stalls is also a disadvantage because the time available for the consumption of concentrates is reduced, no food being supplied while the cows are being washed. It has been held by critics of the two-row system that cows are moved more often and more quickly than is consistent with the giving of their maximum yields.

Considerable variation in the proportion of stalls in the milking house to the size of the milking herd is to be found in practice. Normally the ratio is about five cows per stall, increasing to as many as seven or eight cows per stall in large herds. The number of cows which can be milked simultaneously in a combined washing and milking-stall installation is usually half the number of stalls, one milking machine unit being placed between each pair of stalls, *i.e.,* there will generally be about ten to fifteen cows per unit, depending on the size of the herd. This arrangement allows of every alternate cow being given its concentrates at the beginning of the washing operations, whilst simultaneously cows in the adjoining stalls are being milked and are finishing up their feed. In the two-row, separate washing and milking-stall type of installation, the number of milking units is obviously the same as the number of milking stalls.

Types of Milking House. Most milking houses are of the "walk-through" type where the cows enter at one side of the building and leave, after milking, at the other. The stalls in such a parlour may be placed either "abreast," where the cows stand side-by-side, or "tandem," with the animals standing head to tail.

For a new building of this type, a metal framed structure having the walls and the roof of either corrugated, galvanized iron, or of asbestos cement sheeting will be found to be suitable for most situations. An alternative type of construction consists of reinforced concrete, either built on the site or prefabricated, but this will be more costly to erect than the former. A suitable design is a building having an open span roof, about 18 ft. high to the eaves and 12 ft. to the ridge.

In the "abreast" type of house the width necessary to accommodate a single row of combined washing and milking-stalls should be at least 16 ft., so as to allow not less than 3 ft. 6 in. for an exit passage in front of the standings and ample room in the gangway behind them. Where there are separate milking- and washing-stalls in a double row, a wider building than this will be required, the actual width depending on the arrangement of the two sets of stalls. Generally a width of

from 20 ft to 25 ft. is allowed when the washing-stalls are separate and situated behind the milking-stalls Where other arrangements of the two sets of stalls are adopted, less width will be necessary in the milking house The floor should be of 4 in cement concrete, slightly roughened on the surface, and laid on a solid foundation of hardcore ; it should slope to a shallow dished channel placed about 3 ft behind the standings, which connects with an outside gully, and thence to the
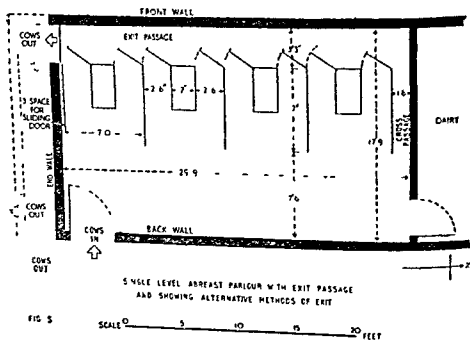
FIG 77—Milking Parlour—"Abreast" type

farm drainage system or other suitable outlet The walls must be impervious and smooth for easy cleansing Ample natural and artificial lighting should be provided, particularly on the rear of the cows An efficient method of ventilating the building is also necessary. Fig 76 shows a good parlour of this type with adjoining dairy

Where both washing and milking are to be carried out in the same standing, stalls for four, six or eight cows, according to the size of the milking herd, are installed in a single line The stalls are best constructed of metal tubing, each stall being not less than 2 ft 6 in w de and having a gate at the front to which is attached a trough for the feeding of the concentrate ration ; the gate, which is operated from the rear of the stalls by a lever arrangement, should open outwards into the exit passage In the "releaser" types of milking machine, the milk is conveyed to the dairy by a common pipe and, therefore, in order to

reduce the length of piping to a minimum the dairy should adjoin the milking house.

One of the disadvantages of the "abreast" type of milking house is that since the cows are standing on the same level as the operator continuous stooping is necessary whilst the work of preparing the udder and milking is carried out.* The "tandem" type of parlour represents an attempt to reduce the tedium thus involved ; the milking stalls are so arranged that the cows stand in one row, head to tail, and on a floor level some 18 inches or more higher than that of the
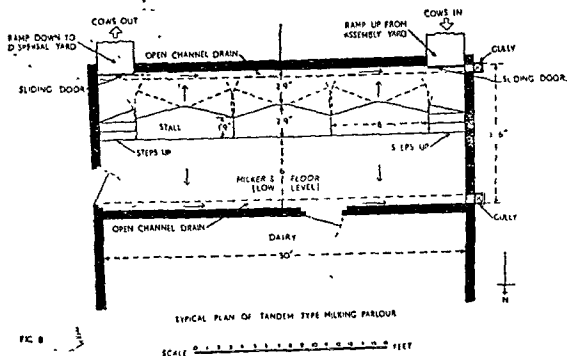
FIG. 77.—Milking Parlour—"Tandem" type.

operator. The building should be about 11 ft. 6 in. wide, the milking stalls being 2 ft. 9 in. wide, the outer passage 2 ft. 9 in. and the operator's floor 6 ft. wide. There may, or may not, be separate washing stalls. In this type of house one milking machine unit is provided for each milking stall (Fig. 77).

It is not always necessary to erect a new building in order to provide milking accommodation on the "parlour" principle. In some cases it may be possible to adapt a cart or implement shed for this new purpose or, in others, the standings at one end of an existing cowshed may be set aside solely for milking operations. These standings, floors and adjacent walls should be constructed for easy cleaning.

Whatever form of milking house is adopted the two most important principles are that provision should be made for easy circulation of

* A "two-level abreast" type of parlour is, however, sometimes constructed.

the cows through the milking stalls without any confusion arising and that the dairy should be situated in a position adjacent to the parlour In all cases water must be laid on for the cleansing of the building and its fittings and for the washing of the cows, and also to the milk room or dairy for the cooling of the milk and for the washing of utensils. A steam boiler of sufficient capacity to ensure efficient sterilization of all milking equipment and utensils is to be regarded as a further essential appurtenance to "clean" milk production

THE OPEN AIR OR BAIL SYSTEM

The system of open air dairying—primarily associated with the name of Mr J Hosier who first practised it, in 1922, on a large scale in Wiltshire—is now fairly common in certain districts, especially in southern England, where climatic and soil conditions permit the cows to be kept out of doors and be milked in the fields throughout the year Whilst in general this system has much to recommend it, its adoption is possible only in areas with low or moderate rainfall, and where the winter weather is never unduly severe Even where this combination of climatic factors exists the keeping and milking of cows in the fields at all times of the year is only practicable on light and well drained soils In some less favourably situated districts the system is restricted to the summer months, whilst at other times one or other of the two systems already described is followed

The essential feature of open air dairying, as practised in this country, is the relatively simple accommodation provided for the various operations connected with the actual milking of the cows This consists of (i) a large collecting pen, constructed by means of movable, light wooden fencing or an electric wire fence, into which the cows are gathered at milking time, and (ii) a milking plant, commonly known as a "milking bail"

The bail has no floor, but is mounted on wheels or skids to facilitate moving by tractor or horses Overhead cover is provided by means of a light roof The bail usually has either 6 or 8 tubular metal stalls of the "walk through" type, with half the number of milking machine units, thus allowing the simultaneous milking of 3 or 4 cows while an equivalent number are being washed in the adjoining stalls The milking machine usually associated with the bail system is of the releaser or releaser recorder type Concentrates are fed to the cows during washing and milking, and some form of trough must, therefore, be provided for this purpose

In the interests of clean milk production it is most desirable that a portable hut be provided for use in conjunction with the milking bail

This hut should be divided into two compartments, in one of which the boiler and engine are housed ; the other and larger compartment should be fitted with a perforated metal floor, and used as a combined milk cooling and washing room. As an alternative, the cooling of the milk, and the washing and sterilization of utensils may be carried out in a dairy at the farmstead, in which case precautions must be taken to protect the utensils from contamination during their transport back to the bail.

Working of the Bail System.—For the efficient operation of the bail, it has been found that the most suitable herd unit consists of from 50 to 60 cows. The cows are passed in rotation through the milking plant, the bail itself being designed to accommodate either 6 or 8 cows simultaneously for washing, milking and the feeding of concentrates, all operations being carried out by not more than three workers.

The bail must pe moved to a fresh site each day, and the collecting pen every third or fourth day, if the fullest advantage is to be obtained from the system. To avoid more than one daily moving of the bail in wet weather, a thin layer of clean straw should be spread on the ground within, and at the entrance to, the bail before the commencement of each milking. The regular moving of the bail and the collecting pen to fresh ground reduces the soiling of the cows and equipment by mud and dung to a minimum, and prevents undue "poaching" of the ground in winter or during wet spells.

Working conditions for the personnel operating a bail in the open fields may be very unpleasant during wet or very cold weather, and in winter, therefore, the bail should be located so as to obtain protection from any natural break that may se available against the prevailing winds. Such a situation, too, will generally also provide some shelter for the cows during the time they are in the collecting pen. During summer, on the other hand, open situations should be sought in order to take full advantage of breezes in minimising the fly nuisance.

Where a bail is transferred from the fields to the farmstead for the winter, it should be put down on a suitably prepared fixed site, *e.g.*, on concrete paving. There should be sufficient concrete floor space for the bail itself and for an exit passage not less than 3 ft. wide, together with an entrance gangway at least 5 ft. wide. To provide shelter from the weather the bail should be roofed over with asbestos sheeting supported by metal, wooden or concrete uprights ; the sides can be filled in with smooth metal sheeting.

The open-air system of dairying, where the only accommodation required is a bail milking plant, obviously involves considerably less capital expenditure on buildings than does either the cowhouse or milking parlour systems. It eliminates the laborious practice of carting

dung from the farmstto to the fields, and does not give rise to any problems connected with the disposal of drainage   On the other hand, the production of clean milk under this system may not be easy and special attention must at all times be given to this aspect   The provision of an adequate and suitable water supply for washing and sterilizing purposes and for the efficient cooling of the milk, as well as for stock drinking, is a primary requirement of any system of dairying   A piped water supply to the fields with service points for the bail is, therefore, a great asset, and avoids the daily cartage of a relatively large volume of water from a distant source

HOUSING OF CALVES

The equilibrium between health and disease is more delicately balanced in young than in older animals and, because of this metabolic instability, bacteria and other parasites not necessarily pathogenic for adults frequently cause disease and death in young animals   Moreover the normal relationship existing between healthy animals of all ages and their environment, which is so easily upset in young domesticated stock, may be disturbed by unhygienic housing or by faulty nutrition   Thus in many instances whilst the terminal stages of a disease may be associated with microbic or parasitic invasion of the body tissues, the primary cause must be sought in extrinsic factors such as those just mentioned.

Three general principles may be formulated with regard to the housing of calves   viz ,—(1) calves should never be accommodated in the cowshed or in any other building housing older cattle , (2) a building intended for the rearing of calves must be well ventilated, admit plenty of daylight, and have proper drainage arrangements , and (3) a calf-house, together with all fittings therein, must be capable of being readily cleansed and disinfected   These requirements do not necessarily mean that the calf house should be an elaborate or expensive affair   Fairly satisfactory accommodation for calves can sometimes be obtained by the adaption of an existing building

The housing accommodation required for calves depends on whether they are to be suckled or hand fed   Where suckling is the system adopted the main buildings needed are a number of fairly large loose boxes say about 180 sq ft in area, or 12 ft by 15 ft , preferably facing south, with an outdoor yard for the cows   The weaned calves can be accommodated either in loose boxes or in sheltered yards having a southern aspect   Pail fed calves may also be similarly accommodated after they are about three months' old.

Where many calves are being reared, those over six months of age

and upwards to about one year old, or until they go out to grass, may be accommodated in groups of not more than 15 to 20 animals in covered or partially covered yards, allowing an area of about 100 sq. ft. per head for yearling cattle and somewhat less for younger beasts. On the smaller dairy farm where economic and other considerations do not usually allow of stockyard accommodation, calves between the ages of six and twelve months can be housed in groups of two or three in loose boxes; these must be large enough to accommodate the animals in comfort, and are preferably each provided with outdoor pens, or alternatively with an exercising-yard common to all the loose boxes.

The Calf-house. Where the pail-feeding system of rearing is practised, it is desirable to accommodate the calves in a building specially designed for this purpose, and in which each calf up to the age of three months can be penned individually; from three months onward to about six months of age the calves may be confined in groups of two to four animals. The main advantages claimed for the individual penning of the youngest calves are: there is no bullying of the younger by the older animals; there is no risk of injury to the navel of the newly-born calf from being sucked by other calves; feeding is easier, and each animal will get its proper ration of food; the more ready observation of individual calves, and consequently the easier detection of illness or other abnormality, is ensured; the risk of spread of white scour and other infectious diseases of calves is reduced.

Since the younger calves will require milk-feeding twice daily, the calf-house should be sited in close proximity to the dairy. The walls and roof of the building should be constructed of good insulating materials in order to minimize excessive changes in the indoor temperature. The floor must be impervious and should either be properly insulated throughout (concrete with air spaces below) or surfaced with a material of low thermal conductivity (e.g. asphalt), so as to secure the necessary "warmth" and yet, at the same time, make cleaning reasonably easy.

Ventilation. Special attention should be paid to the ventilation of calf-houses because of its importance to health in housed animals generally, and more especially because of the ease with which normality may be upset in young animals by adverse environmental conditions. The ideal atmosphere for a calf-house is one that conveys an impression of "airiness," being both warm in winter and cool in summer. The worst possible atmosphere in a calf-house is one which is humid,

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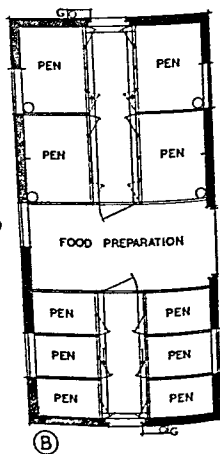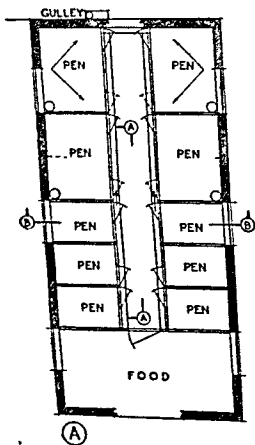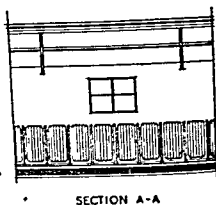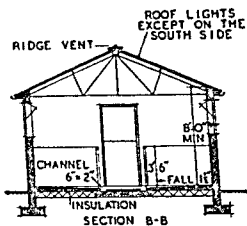
FIG. 78.—Calf-house showing alternative arrangements of pens.

oppressively warm and laden with the effluvia of decomposing excreta. Whilst a great deal more knowledge is still required regarding the precise air requirements of calves, the following have been suggested* as approximations for calves up to about three months' old:—air space 400 to 500 cub. ft. per head, and air flow per head per hour for the calf-house 1,000 to 1,200 cub ft. Draughts, particularly floor draughts, must be excluded from calf-houses and where there is a risk of excessive air currents as in narrow buildings or in exposed situations, solid pen divisions are recommended (see below). The outlet ventilators, as in all animal houses, are best placed in the roof ridge. The best inlets are hopper windows, one window being allowed for each three single pens and *pro rata* for larger pens.

Lighting. The lighting of calf-houses should be planned so as to admit as much sunlight as possible. This is best attained by hopper windows of the type which can be completely lifted out in warm weather. A window of 4 ft. by 3 ft. to each three single pens, i.e. 4 sq. ft. of glass per calf, should meet all requirements. Roof lighting should not be provided if it is southerly in aspect, because it is liable to make the building too hot on warm sunny days.

Pens and Divisions. A suitable plan of interior layout is to arrange the pens along each side of a 4 ft. wide central passage (see Fig. 78), which has a shallow gutter along its length on both sides into which the drainage from the pens is collected, and which leads to a trapped gulley outside the building. A pen to take one calf up to 3 months of age should have a floor area of from 20 to 25 sq. ft., about 5 ft. by 5 ft., or 6 ft. by 4 ft., being suitable dimensions. From three months to about six months' old, when calves are kept in groups and, therefore, probably require somewhat less individual floor space, a pen having an area of 48 sq. ft. (6 ft. by 8 ft.) or 50 sq. ft. (5 ft. by 10 ft.) will be sufficient to accommodate up to three calves.

Partitions between the pens should be about 3 ft. 6 in. high, and may be either solid or open, the latter being formed throughout of tubular steel rails or stanchions set not more than three inches apart. The latter have the advantage that they do not impede air circulation near ground level. Railed partitions have also the definite advantage that they can be made removable, and so allow the conversion of two or more small pens into larger units for older calves. Removable partitions, too, will greatly facilitate cleansing and disinfection of the

*See N.V.M A. "Memorandum on Farm Buildings."

calf-house and its fittings in the event of an outbreak of infectious disease.

Solid partitions are best constructed of concrete or of metal sheeting. Because of its porous surface, which allows lodgment for dirt and, therefore, for bacteria, brick is less suitable. Solid partitions are to be preferred in houses which are liable to unavoidable draughtiness. It is claimed for solid partitions that they separate the calves more effectively and so make the transmission of disease more difficult. This alleged advantage is probably more hypothetical than real, especially in the case of air-borne infections. It can, however, be held with some truth that solid partitions do bar the transference of excretal contaminations from pen to pen at ground level, as well as preventing calves from defaecating directly into adjacent pens as may easily happen with railed partitions. To meet these objections, and also to secure the supposed benefit of calves seeing each other, a compromise between the two types of partition may be adopted. This consists of solid concrete partition to a height of 2 ft. 6 in. with three horizontal tubular iron rails, each 4 ins. apart, set above this, the whole partition being 3 ft. 6 in. high.

It is believed that there is less risk of communicating contagious diseases via the front of the pens, and hence rails or other open work are usually adopted here. These can be provided with openings which allow the passage of the calf's head, so that it can feed from a pail or trough placed in a suitable fitment outside the pen. A gate, 2 feet wide, is necessary in each pen; this should open outwards, and be capable of lying flat against the front partition of the pen.

Timber is particularly unsuitable for the construction of calf-pens. It is less durable than some other more serviceable materials, especially since calves will often lick or chew any wooden surfaces within their reach. If the wood has been dressed with a lead-containing paint, there is also a definite risk of lead poisoning occurring particularly if the paint-work is old and flaking off. Yet another reason against the use of timber is that wooden surfaces do not allow of effective disinfection, and they are consequently a common source from which contagious diseases, such as ringworm, and calf diphtheria, are perpetuated in calf-houses.

Water Supply. A calf must be supplied regularly with fresh, clean drinking water. Feeding experiments have shown that a lack of water lowers the total food consumption of calves, and that consequently the rate of growth is retarded. Even young calves receiving only a milk diet will often drink a little water if it is made available to them. The need for water by calves of all ages is often overlooked, and more

especially during the pre-weaning stage, with the result that the calf becomes thirsty as well as hungry, and tends to gorge itself with milk if given the chance. The water provided for young calves should have the "chill" taken off during cold weather, as the feeding of warm milk at one time and the drinking of ice-cold water at another may quickly lead to digestive upset. Young calves are best offered water from a bucket, but after weaning and when the calves are kept in groups in larger pens, the installation of automatic water-bowls is the best method of making a supply of fresh and clean water available to the animsls whenever they need it.

Other Fittings. It is very desirable that all the fittings of calf-pens, including those for water supply, should be removable, in order that they may be regularly and properly cleansed, and also so that all parts of the fitments can be submitted to complete and effective disinfection between different batches of calves, or, in the event of an outbreak of infectious disease, before healthy calves are admitted to the pens.

The feed-bowl, or trough, may be fitted either inside or outside the pen; in the case of the latter situation, which is probably the better one, the front partition of the pen must have an open panel to allow passage of the calf's head. A bucket-holder is necessary for the feeding of liquid food from a pail in order to prevent spilling; this also may be fitted either inside or outside the pen.

The best method of feeding hay to young calves in from a hay-net, since the meshes of the net prevent a calf- from taking larger portions of hay than it can deal with at one time; this restriction obviates waste of hay through its being dropped on the floor and soiled. For the larger pens holding groups of calves, a low hayrack, having spaces between the rails or slats not exceeding 2 inches in width is probably more satisfactory than individual hay-nets. The rack may either be fixed on the external wall, in which case it may run from end-to-end of the calf-house, or alternatively it may form part of the partition facing the central passage and in this case may be either separate from, or combined with, the feed trough.

Raised slatted floors made of heavy metal laths or of heavy-mesh wire are sometimes used in the United States, whilst in this country a raised sleeping platform of closely slatted hardwood set at about 12 ins. above floor level, has been recommended. If, however, a floor has been constructed with properly laid concrete and is correctly insulated from the ground below, these additional refinements are unnecessary and even undesirable, since they are less easily kept clean than a plain concrete floor surface.
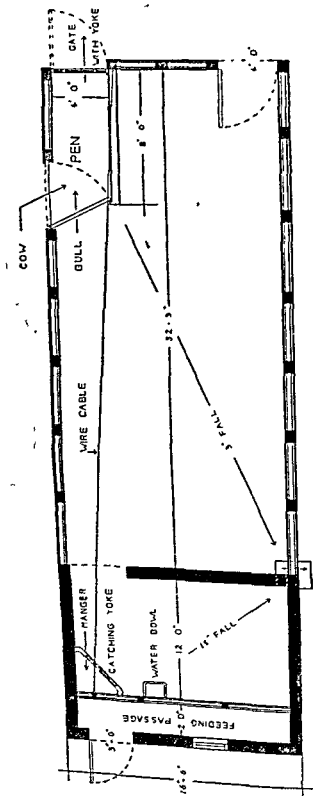
FIG. 79.—Bull Box and Yard—Plan.

HOUSING OF BULLS

There is a growing appreciation of the necessity for higher standards in bull management than those that have customarily been practised in the past, and one aspect of this is the realisation that the accommodation provided for stock bulls on many farms is very unsatisfactory. Common faults in connection with the housing of bulls include badly lit and poorly ventilated quarters, restricted space for exercise, and the complete isolation of bulls from the contact or sight of all other stock. The practice, too, of keeping the bull in a standing in the cowshed is one which must be strongly deprecated, firstly because of the difficulty and danger which must arise in controlling a vicious bull in such a situation, and secondly because, when bulls are housed in this way, it usually means that they are tied up all the year round, except of course when they are led out for service. Continued standing on a hard concrete surface, where a bull has little or no opportunity of altering his position, leads to overgrowth of the hooves and in time to an alteration in the alignment and conformation of the limbs, which is produced by the unnatural stance which the animal is forced to adopt on account of the excessive growth of horn on its feet. In addition, close confinement and lack of exercise have more direct effects on a bull's breeding power. A bull so kept tends to become overfat and slow at service, and there is also some evidence to indicate that lack of exercise in itself may adversely effect sperm production, and entail a lowering in the bull's fertility.

The main considerations in providing accommodation for bulls may, therefore, be summarized as: (1) Safety and ease in handling; (2) a comfortable loose-box or shed for protection from the weather; and (3) provision for exercise. Due attention paid to these points should help to maintain herd sires in good health, vigorous, and in a high state of reproductive efficiency.

If the bull were a subject which was in all circumstances, and at all ages, tractable and easily handled, the ideal arrangement for keeping him would be a paddock of about one or two acres in extent, strongly fenced and provided with a loose-box or open shed for shelter not only against inclement weather, but also as a refuge from direct sunlight on warm, summer days. It is important to ensure that a paddock or other enclosure in which a bull is confined shall have a substantial fence, for experience has shown that after a bull has once broken through a fence, it is much harder to keep him in subsequently. The fence requires to be 5 or 6 feet high, i.e. too high for a bull to
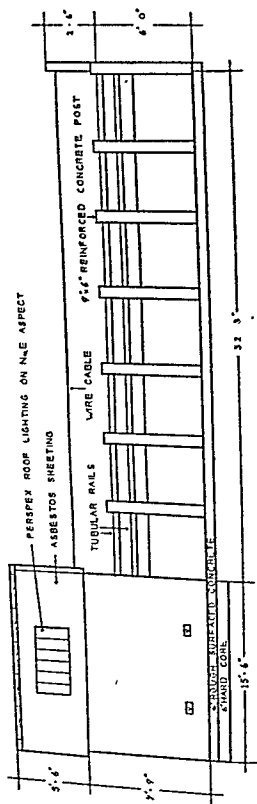
FIG. 80.—Bull Box and Yard—Elevation.

jump over. Solid fences which obstruct the bull's view are not advisable; suitable fencing materials are wooden spars or rails, tubular iron piping, or a combination of heavy gauge wire and barbed wire.

Unfotunately, bulls of most of the dairy breeds tend with increasing age to become bad-tempered and sometimes unruly to handle, and consequently consideration for the safety of attendants usually demands that older bulls at any rate shall be more closely confined than is possible in a paddock. The most satisfactory type of accommodation is a strongly built loose-box to which is attached a suitable fenced exercising-pen or small yard. (See Figs. 79 and 80.) The area of the exercising-pen should be at least 400 sq. ft., with a surface of roughened concrete to prevent slipping.

Loose-boxes for bulls should have 150 to 200 sq. ft. of available floor space. They should be well ventilated and well lighted. Daylight should be admitted from hopper windows set high in the wall, or from roof-lights provided they do not face directly south. Floors should be of roughened concrete, properly insulated, and with a slight slope draining to the outside of the box. Each bull-box should have a main entrance of the half-door type, 4 ft. wide and 7 ft. high, the upper part of the doorway having two strong battens or bars across the opening to prevent any possibility of a bull jumping the lower door when the upper half is left open. Provision should be made on the opposite end of the box for a means of exit, either to a feeding passage or yard, i.e. to outside the bull's quarters altogether.

It is almost indispensable to have some means of feeding a bull without entering the box. This can be done either by partitioning off a feeding passage at one end of the box by means of metal stanchions which allow access to the manger, or, where this is not possible, by inserting in one of the end walls a shuttered opening which gives access to the manger inside the box. The best method for watering is by an automatic water-bowl.

Some means must be provided for catching and tying-up the bull while his quarters are being cleaned out. This may conveniently be done by fixing a strong ring outside the box near the access opening to the manger, and to which he can be tied when feeding. The manufacturers of cowhouse equipment supply a tubular steel corner bull-tie, which has proved a satisfactory device for the restraint of bulls. With this tie there is incorporated a salt-glazed manger, which is firmly set in concrete. The essential part of this fitting consists of a yoke of tubular stanchions set over the manger, and through which the bull has to put his head to reach food in the manger. The yoke can be operated from outside the box, thus obviating the necessity for entering the box in order to catch and secure the bull.

BULL YARD No. 1

BULL YARD No. 2

A

A

A

3' 6"

4' 0"

SERVICE PEN

POSTS 6" × 6"

14' 0"

FOOT REST

FOOT REST

YOKE TIE ON GATE
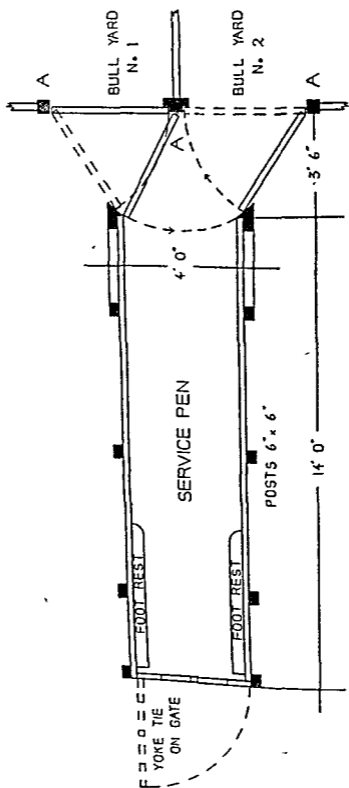
FIG. 81.—Service Pen with direct access from exercising yards.

Service Crate. A safe and useful arrangement for handling a difficult bull, and indeed for any bull, is to have a service crate or pen built as part of the bull-housing unit. This may be constructed either in one corner of the outside yard or pen, or it may be placed completely outside the yard proper. In either case, the route by which the bull enters the crate is via a swing-gate, which is worked so that it is unnecessary for an attendant to have to enter the yard to catch the bull for service. With particularly vicious bulls, an additional safeguard is to have a steel cable running overhead throughout the length of the box, yard and breeding-crate, and to which the bull is attached by a short length of chain. This chain is provided with a spring-hook at one end into which the nose-ring is clipped, whilst at the other there is a ring through which the cable wire runs easily.

The arrangement of a service pen with access from the exercising yard, is shown in Figure 81.

HOUSING OF FATTENING CATTLE

Cattle which are being fattened during the winter may be confined either in cattle courts or yards, in stalls, or in loose-boxes.

Stalls. More often than not a disused cowhouse will be the premises in which stall-fed beef cattle are housed. If a special building is being erected then it should follow the general lines laid down for the construction of byres for dairy cows. Feeding passages are most useful but there is not the same need for smooth impervious walls to the building as there is when it is used for dairying purposes. If a building is being constructed specially for housing beef cattle then its dimensions should be such as will allow it to be readily adapted for other purposes should there be a change of farming policy.

Courts. These may be either open, partially covered or covered, depending upon the prevailing climatic conditions ; similarly the amount of side protection offered by the walls can be varied. In the open yard, shelter is frequently provided in the form of an open-fronted building across one end of the yard the back and two sides of the building being walled or sheeted. Wooden or tubular metal rails constitute a fence on the other three sides of the yard. Mangers are provided under the sheltered portion and the water supply is either from a trough or from automatic water bowls.

Covered or partially covered yards should have walls which are solidly constructed to a height of 4 ft. 6 in., and sheeted above that to

the desired height This height will depend upon the amount of protection required but in all cases an opening should be left between the top of the sheeting and the eaves Asbestos cement sheeting can be used for this upper portion of the walls and it is also a serviceable material for roofing The roof may cover the entire yard or merely the portions nearer to the walls leaving the central part open to the sky

An area of about 100 sq ft per animal should be allowed in the yards though this figure may be reduced to a minimum of 60 sq ft. when large numbers are kept

HOUSING OF PIGS

In recent years increasing emphasis has been placed upon the important relationship which exists between housing conditions and health and productivity in pigs Unlike most domestic animals which possess coats either of wool or thick hair, the pig is but poorly protected against cold, such hair as it has being ineffective in this connection In the older pig compensation is provided by the thick layer of subcutaneous fat which is developed but young pigs, lacking this, are particularly susceptible to the effects of climatic conditions

Howie, Biggar, Thomson and Cook[*] in an experimental study of pig rearing reached the following conclusion :—"In nine pig rearing experiments designed to probe the causes of ill health among young pigs farrowed and reared indoors the findings suggested that the main cause of trouble was that the buildings were too cold, draughty and damp and that the superior health of the pigs farrowed out of doors appeared to depend less on their access to iron and unknown nutrients in the soil and grass than to the greater comfort afforded by the wooden arks huts in which the sows and litters were housed " Naftalin and Howie[†] demonstrated that hepatic lesions with accompanying clinical symptoms of listlessness and unthriftiness could be brought about by rearing young pigs in a cold and damp environment and prevented by affording them additional warmth. Inglis and Robertson,[‡] Lamont, Luke and Gordon § and many other authors have stressed that warmth and clean dry surroundings are of fundamental importance in pig husbandry

Housing requirements will vary in accordance with the different types of stock which are kept and with the system of management

[*] Howie, J W., Biggar, W A., Thomson, W., and Cook, R. (1948) J A/
    Sci., 39, 110
[†] Naftalin, J M., and Howie J W (1949) J Path Bact, 61, 319
[‡] Inglis J S S, and Robertson, A. (1949) Vet Rec., 61, 141
§ Lamont, H C., Luke, D., and Gordon, W A. M. (1950) Vet Rec 62, 7:

adopted. Thus the breeding and rearing of pigs requires accommodation different from that needed for pigs which are being fattened, whilst the type of housing is also dependent upon whether an outdoor or indoor system is followed.

Outdoor accommodation for Breeding and Rearing. Under the outdoor system of management accommodation is required firstly for sows and gilts, both empty and in-pig, and then for farrowing and for the subsequent rearing of the young pigs.

In-pig sows and gilts are usually run together in groups of up to twenty and allowed free range. Electric fencing may be used to limit the area, a single strand usually being sufficient though a double wire may be necessary when the pigs are first introduced. The shelter provided may be only temporary and constructed from straw, wire netting, corrugated iron and hurdles or a more permanent type of building may be used. In the latter category are large movable wooden huts or huts of the Nissen type, the main essentials being that they should be water-proof, give protection from the prevailing winds and, especially in cold, wet districts, be provided with a strong wooden floor which is kept covered with clean litter. Light, well-drained land is desirable for this system of management and whatever type of shelter is provided it should be moved often enough to prevent the surrounding ground becoming fouled and badly poached.

For farrowing and rearing small wooden huts, either rectangular with a sloping roof or in the form of arks, are frequently used. Each hut will accommodate one sow and her litter. The sow is tethered by means of a harness and chain the latter being secured to a pin in the ground and of just sufficient length to allow the sow to enter and lie down in the house provided for her. The sow should be tethered ten days or so before the time when she is due to farrow and remain so tethered until her offspring are weaned. The huts and tethering pins must be moved frequently. Alternatively, farrowing and rearing quarters may be provided in fold units, that is portable wooden huts about 8 ft. square with attached runs, 10 ft. in length, constructed from galvanized sheeting on wooden frames. The huts should be fitted with skids so that they can be readily moved by means of a tractor or horse. This movement on to fresh ground must be carried out at least every other day owing to the limited area of the run. In some cases whilst the in-pig sows are run out at pasture they are brought indoors for farrowing and for the subsequent rearing of the piglets. The type of farrowing pens provided will be similar to those described on page 261.
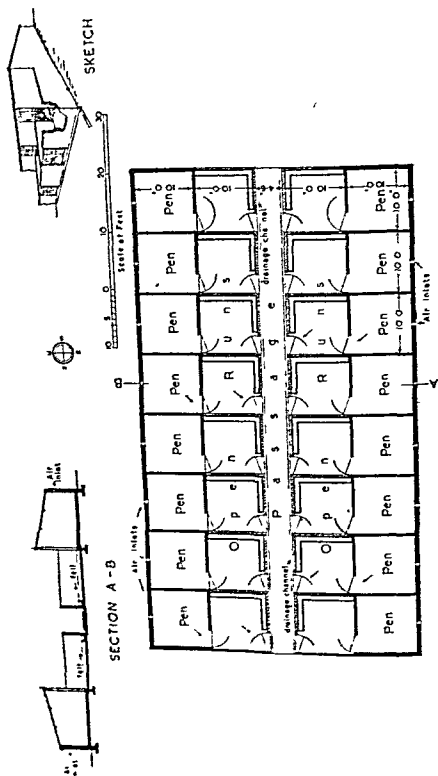
Fig. 82.—A range of Pig pens with open runs.

Accommodation for Fattening Pigs. Store pigs may be kept out of doors up to the age of twelve to fourteen weeks, being either run at pasture with huts provided for housing, or kept in yards which are either partly covered or have some form of shelter opening on to them. Fattening is sometimes carried out in yards, the pigs being kept by themselves or, occasionally, along with cattle. In the latter case the pig feeding troughs should be placed in a fenced off portion of the yard with a "creep" through which the pigs are able to pass but which prevents the cattle having access to the pigs' food.

Fattening, however, more usually takes place in some type of house, ranging from the sty with the open run to the totally enclosed pig-house containing a number of feeding pens and possibly accommodation also for breeding sows and their litters.

The materials used in the construction of permanent pig houses will be to some extent determined by local circumstances, but certain principles may be laid down. Outside walls should in all cases be constructed with a view to conservation of heat within the building during cold weather and for this purpose 11 in. brick cavity walls are best and a proper damp course should always be provided ; if concrete is used it should be at least 8 in. thick. The inner surface of the walls of the building and the partition walls of the pens should be given a smooth, hard face with cement, the walls to a height of at least 4 ft. and the partitions on all surfaces and top edges. Asbestos cement sheets are useful for roofing but, whenever possible, the roof should also be lined with some suitable lining-board. Tiles or slates may be used instead of asbestos cement sheets but these will increase building costs considerably. For the proper functioning of the Scandinavian type of piggery a ceiling should always be provided (see below).

Concrete floors are satisfactory provided they are air-insulated by one of the usual methods and are properly sloped for drainage purposes. Troughs of glazed earthenware or galvanized iron are more satisfactory than those of concrete which are apt to become pitted and difficult to clean. Provided they are kept clean, fixed troughs are generally to be preferred to movable ones ; the latter have the advantage that they can be taken out for cleansing but, on the other hand, are usually easily overturned by the pigs.

The type of accommodation provided may be either in the form of a series of enclosed pens with open runs adjoining or, alternatively, a totally enclosed pig-house on the Scandinavian principle but modified in accordance with usage in this country. In each case the unit may consist either entirely of fattening pens or provision may also be made for a series of farrowing pens.

FIG. 83.—A Scandinavian Pig House

(Reproduced from the Ministry of Agriculture and Fisheries Bulletin,
No. 32, *Pig-Keeping*. By permission of the Controller, H.M.
Stationery Office.)

Fig. 82 is an example of the "in-out" system *i.e.*, a range of pens with open runs attached. *Feeding troughs are placed in the open runs and a central passage facilitates access.* Essential measurements are shown in the diagram. If desired a hanging sackcloth can be fitted on the openings between the pens and the runs to lessen draughts and maintain warmth in the pens.

The Scandinavian Piggery. The completely enclosed type of house of Scandinavian origin has been widely adopted in Great Britain but very frequently has failed to give satisfaction here owing to the fact that several of the most important features of the original have been ignored.

A typical Scandinavian house is shown in Fig. 83. The pens are arranged on either side of a central feeding passage, those on the one side being for sows with litters and those on the other for the rearing and fattening of pigs after weaning. Each pair of the former is separated by a narrow pen designed for the tending of young pigs. At the back of the pens on each side there is a passageway from which the pens are walled off except for a narrow door. When all these pen doors are in the open position the passage is divided into sections separate from each other, and each section acts as a dunging passage for the pigs in the pen which communicates with it. For cleaning out, the doors are closed towards the pens and the whole length of the passage is open for the removal of dung by barrow. In many cases these doors *constitute the only means of entrance to the pens in order not to reduce* the amount of trough room available on the feeding passage side. The troughs are arranged so that they may be readily filled from the feeding passage, the wall over the trough frequently being made *in the form* of a shutter hinged above so that the trough can be cut off from either the passage or the pen as required. Alternatively, instead of this hinged shutter a fixed partition may be set longitudinally but not centrally over the trough allowing enough room for food to be poured in from the gangway but not enough space for the pigs to escape. A bacon weight pig requires not less than 12 in. of trough room and, apart from dunging space, about 9 sq. ft. of floor space.

The original Scandinavian form of piggery was built so as to provide as much protection as possible in severe climatic conditions. Important points in this connection are the provision of an insulating loft overhead, a thick bed of ashes or hollow bricks under the concrete floor, walls 16 ins. thick with a considerable cavity filled with dry ashes and, in many cases, heating stoves. In modifying this type of piggery to conditions in this country, *many of these features have been ignored* on the grounds that climatic conditions are less severe here, but in

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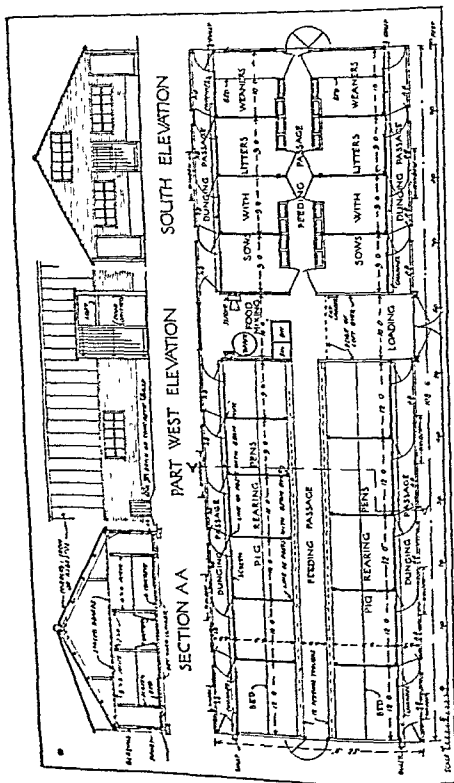
FIG. 81.—Pig-rearing House on Indoor System for 200 pigs after the Scandinavian Plan.
See Acknowledgment, Fig. 83.

consequence the resulting buildings have been cold and damp and have frequently been the cause of much unthriftiness and many losses especially in young pigs.

The Scandinavian piggery illustrated in Fig. 83 has a complicated ventilation system with inlets in the form of cranked flues high up in the walls and continuous outlet ducts near the floor communicating with vertical flues in the walls thence to central outlet shafts passing through the loft to the ridge. In some buildings provision is made for warming of the air at the point of inlet.

The difficulties associated with providing proper ventilation and at the same time maintaining an adequate temperature have already been discussed (see pages 136 and 140). The complicated Scandinavian system is probably unnecessary in most parts of this country but some authors have suggested that provision for heating incoming air might be advantageous in some situations. Under ordinary conditions, however, in the absence of any well-attested standards it can only be recommended that outlets should be at the highest possible point and inlets in the side walls either in the form of hopper windows or specially constructed ventilators. Both inlets and outlets should be adjustable so that they can be closed to the degree necessary to maintain a reasonable indoor temperature in cold weather. Lighting may be either from roof or wall lights which should be placed so that the pigs are not exposed to strong direct sunlight for long periods (see page 162).

A pig-rearing house which retains some of the features of the Scandinavian system is shown in Fig. 84. The rearing pens are graded in size from 9 ft. by 9 ft. 9 ins. up to 12 ft. by 9 ft. 9 ins. exclusive of the dunging passage which is 3 ft. 3 ins. wide. Farrowing pens are 9 ft. by 9 ft. 9 in. As shown in the diagram each pen is provided with a wooden bed but if there is a well-insulated concrete floor this may be dispensed with. The whole building, with the exception of the loading portion in the centre, is covered with a loft. Inlet ventilation is provided by hopper windows and outlet through the space-boarded loft floor and thence to the ridge where the corrugations of the roofing permit egress of foul air. Asbestos cement sheeting is preferable to corrugated iron for the roof.

Shanks* has given special consideration to the problem of heat conservation in pig houses and Lamont † has described the modification of a piggery in Northern Ireland in order to achieve this. This piggery consisted primarily of a large concrete building with a concrete floor and was divided into a number of pens separated from each other and from a central feeding passage by a concrete wall 4 ft. high. Each

* Shanks, P. L., (1942). *Vet. Rec.*, 54, 233.
 mont, H. C., Luke, D., and Gordon, W. A. M. (1950). *Vet. Rec.*, 62, 737.

pen communicated with an outside run. The attention of Lamont and Shanks was drawn to the premises owing to the high mortality amongst young pigs in spite of good management and hygiene. The building was altered in the following way :—

After relaying the floor with air spaces, the pen partitions were continued up to the roof with wooden sheeting, the central passage being thus cut off from access to the pens except by a door. The roof was also lined with wooden sheeting and the roof lights made of double
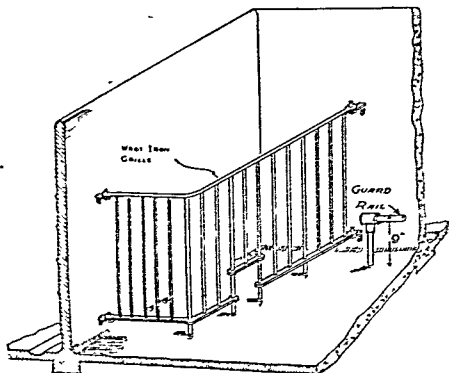
FIG 85 —An arrangement for "creep" feeding in a farrowing pen

glass to give a continuous air-space in the roof. A wooden sleeping compartment was constructed inside each pen and inside this a sloping shelf under which the young pigs could lie. The entrance to the sleeping compartment and the space beneath the shelf were each protected by sacking. A porch on the inside of the doorway leading to the outside run was designed to prevent direct access from the pens to the runs. As a result of these alterations the mortality rate amongst young pigs was reduced to negligible proportions.

In a discussion of the above mentioned paper Shanks* gives plans of buildings which have been designed in the light of the experience thus gained.

* Shanks, P. L. (1950). Vet. Rec. 62, 743.

Farrowing Pens. When indoor pens are provided for farrowing the dunging passage may be dispensed with if desired, since the amount of dung to be dealt with is comparatively small. Some means of conserving or providing additional heat in these pens is desirable in the form of either electric radiators or a covering for the sleeping floor of the pen at a height of about 4 ft. from it ; this covering may be of simple construction consisting either of boarding or of a wire netting frame upon which sacks can be placed. A farrowing rail may be fitted to the walls of the pen at a height of about 8 ins. from the ground and projecting 10 ins. from the wall. Such a rail is designed to prevent crushing of the young pigs *during the first few days of life. In addition, facilities for "creep" feeding should be made either in the* form of a railed-off portion of the pen to which only the young pigs have access by means of a small aperture (Fig. 85) or as in Fig. 83 by constructing a narrow pen between each pair of farrowing pens and then dividing this into two by a partition parallel to the feeding passage ; access from the farrowing pens on either side is by means of small pop-holes so placed that the two litters are separated by the partition.

Farrowing Crates. The farrowing crate is designed to reduce losses from crushing of young pigs by a heavy sow during the first week of life and is often regarded as more satisfactory than the provision of farrowing rails in an ordinary type of pig pen.

The crate consists of a wooden "box" for the sow with nest boxes at ground level on either side for the young pigs. Suitable measurements for the crate are 7 ft. long by 2 ft. 6 ins. wide by 4 ft. high. The sides terminate 9 ins. above the floor so that a space is left by which the young pigs have access to the sow from the nest boxes. The ends of the crate consists of doors which slide upwards to open. The nest boxes should be 1 ft. 3 ins. wide and 1 ft. 3 ins. high sloping to about 10 ins. on the outside and fitted with a hinged lid. One box is attached to each side of the crate and they extend along its full length.

The crate should be of substantial construction and there should be means of adjusting the internal space available by means of boards which fit on the inside. This is necessary to limit the movements of a small sow which might be a source of trouble if the crate was too large for her.

The sow should be placed in the crate a day or two before she is due to farrow and will remain there with her litter a week to ten days afterwards, being allowed out twice daily for feeding and defaecation. She should not require any attention during farrowing and the little pigs soon take advantage of the boxes in which should be placed either

short cut straw of chaff After the crate has been vacated by the sow and her litter it should be cleansed and disinfected before being used again

HOUSING OF GOATS

Milking goats should be housed in buildings which are dry and well ventilated and are capable of being kept reasonably warm in the winter months In present circumstances it will usually not be possible, owing to shortage of materials to construct a building specially for housing goats, but existing premises, a disused stable or poultry house for instance, can often be readily adapted for the purpose

The goats may be kept either in loose-boxes or in stalls A suitable size for loose-boxes is 4 ft 6 ins square with walls 4 ft high. When stalls are used they should be 2 ft to 2 ft 3 ins wide, 3 ft 6 ins deep and divided by partitions 4 ft high in front and 3 ft high at the back. Strongly constructed hay racks with bars about 2 ins apart, and iron rings 9 ins in diameter into which food and water pails can be inserted should be provided The best material for flooring is cement concrete, laid with air spaces and suitably sloped for drainage purposes The goats may be bedded on wheat straw peat moss or other suitable litter, or raised, slatted, sloping platforms constructed from 2 ins by 2 ins timber may be used which fit either into the stalls or into a corner of the loose box as the case may be Inlet ventilation and lighting are best provided by hopper type windows with air outlets at the ridge when possible.

Goats in stalls are usually tied up by means of collars and chains, the chain being free to slide up and down a vertical iron bar fixed to the stall partition

Milking may be carried out in the stall but many people prefer to use a milking bench approximately 4 ft. by 2 ft and raised 18 ins. from the ground. At the front end of the bench a "guillotine" may be fixed in which the goat's neck is securely held whilst milking, or the animal may merely be chained up in the usual way as it stands on the bench.

During the summer months goats may be kept tethered out at pasture all the time if a light movable shelter is provided Under this system the goat is tethered to a stretched wire by means of a chain which is just long enough for the animal to lie down comfortably in the open fronted shelter The shelter, though of simple construction and light enough to be moved easily, must be strong enough to withstand rough usage by the goat. The tethering wire and the shelter must be moved regularly on to fresh ground

HOUSING OF POULTRY.

For the maintenance of good health in its widest sense, in poultry as in other animals, there are two main essentials. First, a sound, vigorous constitution in the stock—and second, the management of the birds, which includes housing on hygienic and sanitary principles, care of the land on which the birds are kept, and proper feeding. Stamina is an important factor, and birds that have inherited great constitutional vigour seem able to thrive, for a time at least, under the most unfavourable conditions. Sooner or later, however, disaster is bound to overtake the poultry keeper who houses and manages his flock in defiance of the laws of hygiene and sanitation.

That fowls do respond to good housing is now generally admitted, and the modern poultry farmer realises that he must lay out a considerable amount of capital on housing if his business is to be successful.

While the cleaning and disinfecting of the houses is a comparatively simple operation, maintenance of the surrounding land in a clean and fresh condition is one of the greatest problems with which the poultry keeper has to contend. Fowls are susceptible to infection by a large variety of bacteria and internal parasites, and it is impossible to keep birds on a restricted area for any length of time without marked ill-effects on health and egg production. Fresh pasture which has not carried poultry previously is ideal for keeping up egg yield and for maintaining the health of the stock. Few poultry keepers, however, have unlimited land at their disposal, and they must adopt the method of housing and management best adapted to the conditions. The colony system, the folding system, the alternate run system, and the purely intensive method, are all attempts to overcome the evils arising from "tainted" land.

Types of House for Laying Birds

Poultry houses are of many types and sizes and each type is associated with a definite system of management. Thus, one type is specially adapted for free range, where a large area of land is available, another for semi- or total confinement, and so forth. The various types include:—(1) The large permanent house, (2) the portable solid floor or slatted floor colony house, (3) the fold unit, (4) the straw house, and (5) the stone or brick house.

(1) The Large Permanent House. This type is particularly suited to the intensive method of poultry keeping. The birds are kept entirely indoors, either on solid floors with litter or in individual lay-

ing battery cages. It is also used for the semi-intensive, or alternate run system, but here a major disadvantage is the contamination of the
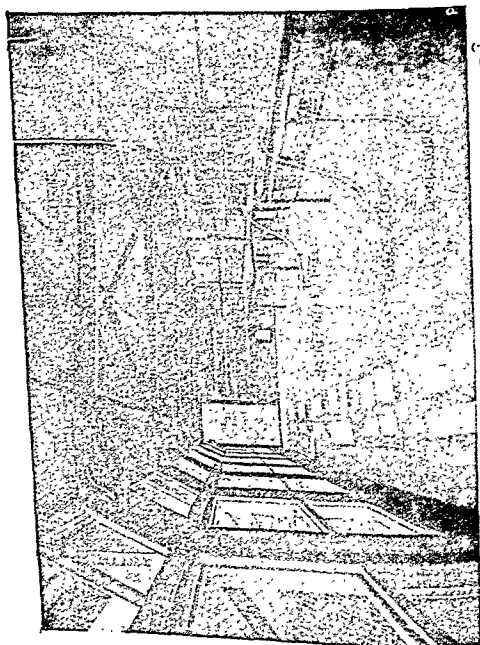
FIG. 86.—Large Permanent Laying House (inside).

ground immediately surrounding the house. For the fully intensive system the advantages of such a house are economy in ground space and saving of labour, as a large number of birds can be accommodated

under one roof. A drawback is that large permanent houses are expensive to erect and maintain, but increased egg production over a
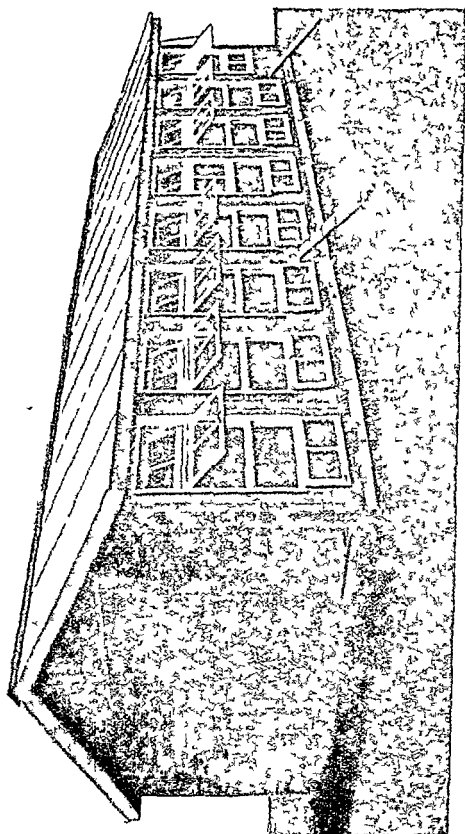
FIG 87—Laying House (outside)

period of years may offset this Broadly speaking, they are of two patterns, the lean-to and the span roof The latter is to be preferred,

as ventilation is more easily controlled The half-span is the most common type particularly for battery work, but the three-quarter span is also used Some of the features of a house suitable for the keeping of fowls on the solid, littered floor system mentioned above are first dealt with —

Size —A usual width is from 10 to 12 feet for a medium sized house, while for a large house measuring up to 100 feet in length, a
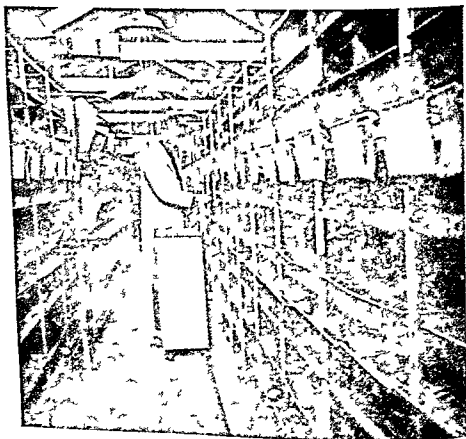
FIG 88 —Interior of a Laying Battery House

width of from 12 to 15 feet may be allowed As a feature of the large intensive house is the drop shutter, or window placed about 18 inches above floor level and running the full length of the front of the house, it is essential that the house be wide from front to back, otherwise there will be risk of draughts

Floor Space —From 4 to 6 square feet per bird should be allowed, according to the size of the house, the larger amount being necessary for the smaller house

Ventilation —Outlets are usually provided at the ridge, and must be well baffled to prevent snow from driving in In addition to the drop

shutter already mentioned, there should be windows all along the front of the house, arranged to fall inwards. Adjustable windows should also be placed just above the floor level at the back of the house, so that the whole of the floor space may be well lighted.

Height —This will vary according to the size of the house, and may be from 7 to 10 feet at the ridge and from 4 to 5 feet at the eaves.

Roof —A well-protected, rain-proof roof is essential. Wood, covered with one of the patent preparations of felt, is most commonly used.
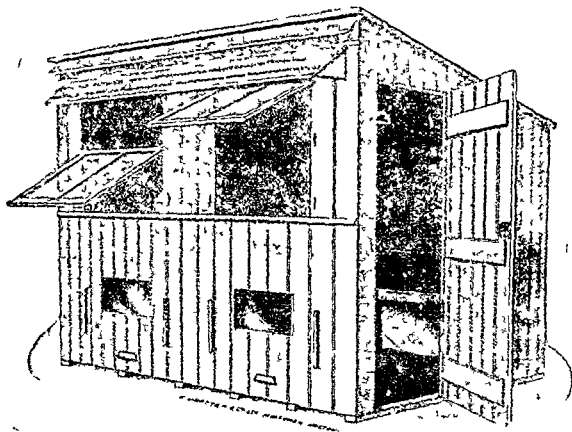
FIG 89 —Small Solid-floor House

Fittings —These consist of perches, dropping boards, nests, food hoppers and water dishes. The perches should be 2 inches broad and placed not higher than 3 feet above floor level. A perching space of 8 to 12 inches may be allowed for each bird. Below the perches are placed dropping boards, which, like the perches, should be removable. The nests may be placed at the ends of the house away from the direct light and should be provided with some means of closing at night. One nest for every three or four birds is ample. The dry mash hoppers should be of sufficient size to enable a number of birds to feed at once. One or two long hoppers are better than a number of short ones.

Both hoppers and water dishes should be raised up from the floor to prevent the birds filling them with litter The floor of the house may be covered with straw, chaff or peat moss litter, which should be renewed as soon as it gets damp, dusty or dirty

Large houses may be divided into sections, but in any case it is advisable to put short partitions across at intervals, so as to eliminate the danger of draughts

In the case of the *laying battery system* the house may be of much the same design as already described, but particular attention must be given to its dimensions in order to allow of ease of working between the battery units and yet ensure the maximum use of the floor space available (See Fig 88) The laying cage must be so constructed that it is readily cleaned and that egg eating is avoided

The *Deep Litter System* is a modification of the intensive system where, instead of a thin layer of litter which is changed frequently, the litter is allowed to accumulate over a period of a year or more The successful operation of the system depends upon the correct management of the litter, either wood shavings or chopped straw being best for the purpose To commence the process the floor of the building should first be sprinkled with hydrated lime and then a thin covering of sifted compost or horse manure should be applied prior to covering with litter to a depth of about four inches This treatment will favour bacterial activity within the litter which as a result will, after a period of time, become dry and powdery Subsequently the surface is lightly stirred over at intervals to keep the bed in an absorbent condition and a small amount of fresh litter is added as a top dressing whenever this is done Practically any type of permanent house is adaptable to this system allowing about 4 sq ft per bird The best type of inlet ventilation is a baffled entry about 2 feet up, so placed as to provide a gentle cross-current Ridge outlets should be provided Fittings should be readily removable and every effort made to get an even distribution of droppings, for this purpose a raised type of feeding trough with attached perches and which can easily be moved to different parts of the house is most useful

(2) The Portable Colony House. (a) *Solid Floor Type* —This is

essentially a house for the general farm, or where there is plenty of land available The house must not be too heavy, as it has to be moved periodically in order to give the birds clean ground It may be made in sections so that it may be easily taken to pieces for moving Some types are fitted with skids or wheels which permit of them being drawn by a horse or tractor The internal fittings are much the same as for the permanent type of house From 3½ to 4 square feet per

bird will be sufficient floor space, as the fowls will spend a large part of their time out of doors

(b) *The Slatted Floor House.*—This type has become popular on farms for the *reason that it saves labour and entails a smaller initial outlay per bird than the preceding* Its chief feature is a floor consisting of wooden slats, placed about 1 inch apart, on which the fowls sleep. Removable dropping boards or trays are placed a few inches below
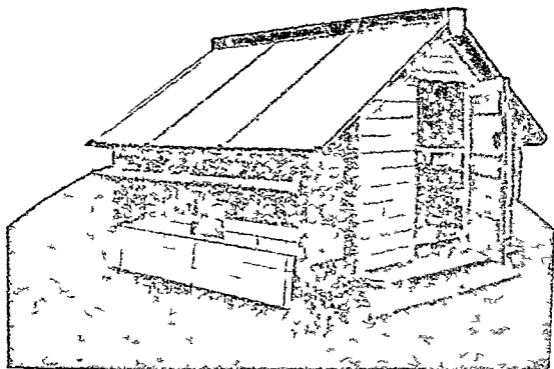
FIG 90 —Slatted floor House

the slats The ends and sides of the house below the slats are open, which gives a constant circulation of air under the birds, and there is *also ridge ventilation* The house is fitted with nest boxes, food and water vessels, but there are, of course, no perches The usual allowance of floor space is about 1 square foot per bird, as against 3 4 square feet in the solid floor type As the house is only used for sleeping quarters, plenty of land is necessary, and not more than 100 birds to the acre should be allowed For winter egg production this house is less suitable than the solid floor type as it provides little comfort for the birds during inclement weather

(3) Fold Unit. This is usually apical in shape to avoid damage by other classes of stock Each unit is self contained, holding 15-20 birds,
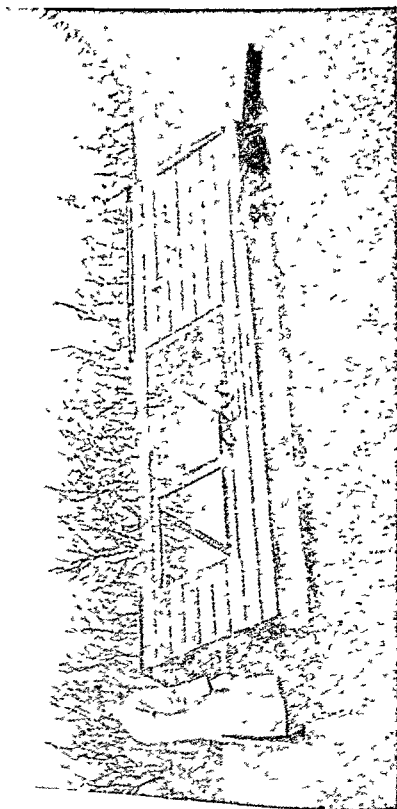
Fig. 91.—A typical Fold Unit

with a slatted floor, sleeping and nesting compartment at one end, and a wire netting run at the other. The overall size of the unit is usually about 18 feet long by 5 feet wide, including the sleeping and nesting compartments which is about 5 feet square. There are no dropping boards under the slatted floor, the faeces falling through on to the ground.

The unit, which must be of light construction compatible with structural rigidity and strength, should be moved to fresh ground daily, thus preventing land contamination and ensuring adequate distribution of the manure (Fig. 91).

This system is followed mainly by the general farmer who has ample light, level land available.
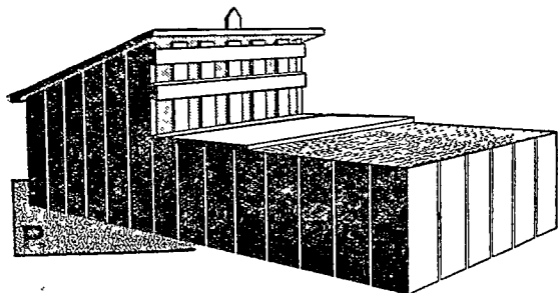
FIG. 92.—Wooden Chicken Coop and Run.

(4) *The Straw House.* This is a cheaply constructed house, suitable for use on the farm. The framework is of wood, covered with netting; to this is laced a thick thatch of wheat or rye straw. It is usually made from 10 to 12 feet high, and the pitch must be steep so as to allow the rain to run off easily. A house of this nature keeps a more even temperature than a wooden house, and it is recommended for cold, exposed districts.

(5) *The Stone or Brick House.* The old type of poultry house commonly seen on the general farm is usually dark and badly ventilated and is often needlessly high. Where the necessary alterations can be carried out so as to bring it up to proper hygienic standards, this house may sometimes be converted into comfortable quarters at a comparatively small cost.

THE HOUSING OF CHICKENS

There are many methods of housing chickens, from the oldest and simplest—the broody hen and coop—to the latest and most complicated—the electrically heated battery brooder

The Hen Coop. Coops may be of metal or wood and are of various designs They should have ample ventilation and must be fitted with a shutter for closing at night to keep out rats For very young chicks
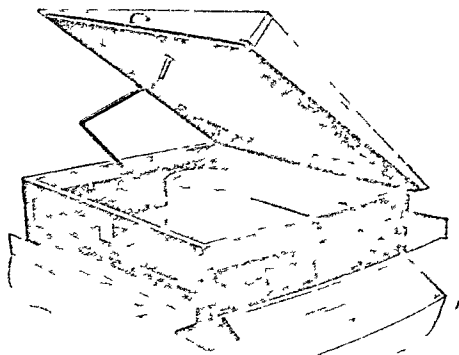
Fig 93 —Hover

it is advisable to have small wire runs attached Coops and runs should be moved every day to a fresh piece of ground

The Outdoor Brooder or Foster mother. This consists of a small inner compartment, heated by a lamp, and an outer compartment These brooders give good results in fine, dry weather, when the chickens can get out into the open, but are not recommended for winter rearing as the birds tend to stay too much in the warm compartment where they do not get the benefit of fresh air and sunshine A brooder

to hold a hundred recently hatched chicks quickly becomes too cramped for this number, since the birds grow rapidly and need a correspondingly increased amount of air space. Some brooders are made so that when artificial warmth is no longer required the whole can be quickly converted into a cold brooder ; this arrangement allows for the extra space needed by the growing chicks.

The Small House and Hover. This is an excellent method for rearing in small units, particularly if the house has a small run attached and the whole is made portable so that it can be periodically
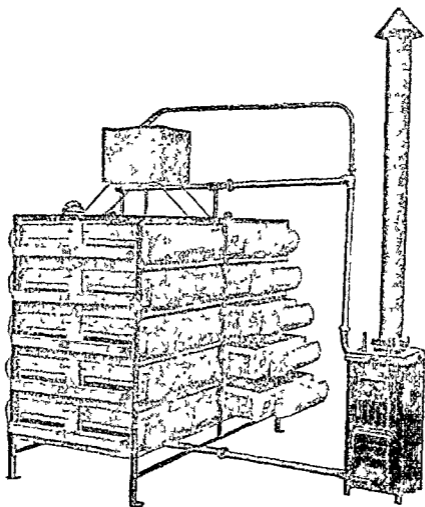
FIG. 94 —Battery Brooder.

moved on to fresh ground. A house measuring 7 feet by 7 feet and about 6 feet high will accommodate 100 chicks up to the age of six or seven weeks. This allows a floor space of about $\frac{1}{2}$ square foot per bird. A window, made to open, should be placed a few inches above floor level, so that there may be an ample supply of fresh air and direct sunlight. A lamp-heated hover is placed in the house, preferably of the type which is fitted with a wire floor and a movable tray beneath ; this arrangement ensures adequate bottom ventilation and prevents

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contamination from the droppings. The chicks may be kept entirely indoors for the first week, after which they should be allowed out to the ground if the weather is suitable. When the birds are old enough to do without heat, the hovers may be removed and a sleeping rack introduced. This may be made of slats 1½ inches broad and ¾ inch apart, nailed to a frame standing about 6 inches above floor level. A rack of this description prevents the birds from huddling and keeps the house clean and dry.

The small house with hover has certain advantages over the outdoor brooder ; the birds have more head room and there is less risk of over-crowding ; it is more suitable for winter rearing ; it may be fitted with
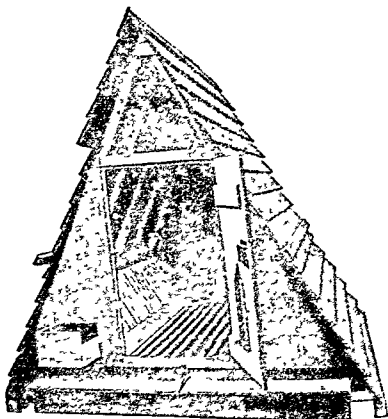
Fig. 95.—Slatted Ark for Chickens after they have left the Brooder House.

perches and used as a laying house, when no longer required for chickens, whereas the outdoor brooder is not convertible for any other purpose.

The Brooder House. The large brooder house, in which the chicks are kept intensively for the first seven or eight weeks, is widely adopted where large numbers of chickens are to be reared. The house may be

of any length, but the breadth should not be less than from 12 to 15 feet to allow of a three-foot gangway at the back, from which open off the different sections. The size of the sections will depend on the style of the house, but not less than a $\frac{1}{2}$ square foot per chick is necessary. The front of the house is fitted with drop shutters or windows, placed about 18 inches above floor level, so that the whole area may be flooded with the direct rays of the sun. South-east is the best aspect for the house. Smaller buildings are usually heated by separate oil-burning hovers in each section, but in the large houses a central hot water or electrical system is generally adopted.

From the brooder house, the chickens are usually drafted into *slatted arks*. These are made on the same principle as the slatted floor house but are smaller, more lightly constructed so as to be easily moved by hand. (See Fig. 95.) They may, or may not, be fitted with removable dropping boards. It is necessary to put a fairly large number of birds in the ark to begin with, so as to prevent chilling. As the birds develop, the numbers in each ark must be reduced.
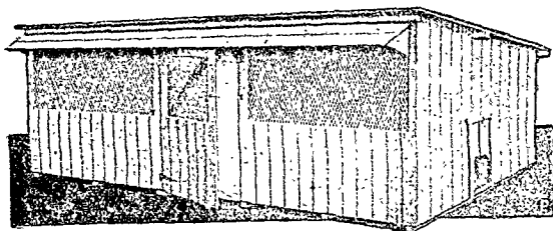
FIG. 96.—Duck House.

Battery Brooders. These consist of a number of wire cages arranged in tiers, in which the chicks are placed as they are taken from the incubator. They are of many types and patterns, and may be heated from a solid fuel stove or by electricity. As these brooders take up a comparatively small space in proportion to the number of chicks they carry, they are widely used where hatching is carried out on an extensive scale. There are many problems connected with the feeding and management of battery-reared chicks which cannot be discussed here, but it is now generally considered that the use of battery brooders is best limited to the rearing of commercial egg-laying stock alone ; for potential breeding stock, one or other of the systems already described is preferable.

HOUSING OF DUCKS

The duck house differs somewhat in designs from the henhouse; the common practice of housing ducks with other fowl is not recommended. For ducks a house is merely a shelter for the night, a protection against enemies and a means of securing the eggs. Ducks lay very early in the morning, and if not housed at night they tend to lay elsewhere and the eggs may be lost. The birds are very susceptible to damp, and require a dry bed to sleep on. Poor egg production may often be due, in part, to unsuitable sleeping quarters. An open-fronted house, 4 feet 6 inches at the highest point, will ensure that fresh atmosphere so essential for water fowl. A wire or slatted

SOUTH ELEVATION.
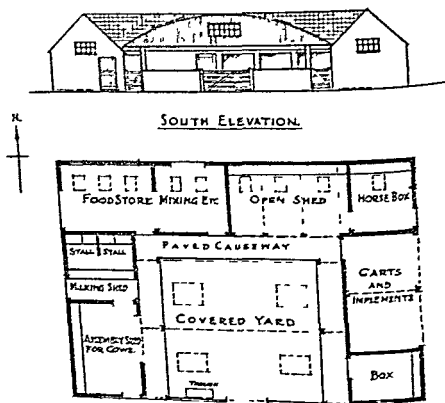
FIG 97—Buildings for a Small Farm.

floor covered with clean straw, which must be constantly renewed is to be preferred to a solid floor, as this is very difficult to keep dry. Plenty of litter should be provided, as the birds like to bury their eggs in this. A floor space of about 2½ to 3 square feet per bird is ample if the ventilation is good. Wide openings should be provided in lieu of small pop holes owing to the excitable nature of the birds

HOUSING OF TURKEYS

A house is not an absolute essential for adult turkeys. They prefer to roost in the trees, where they appear to obtain all the shelter they require. For convenience, however, a house may be provided. This must be high, not less than 10 feet, and very well ventilated. A floor space about 10 square feet per bird should be allowed. The perches should not be more than $2\frac{1}{2}$ feet from the ground, and not less than $2\frac{1}{2}$ inches broad in order to support the weight of the birds. There is no need to supply nest boxes, because, like ducks, the birds prefer to lay in the litter in a dark corner of the house. For rearing turkeys where the land may be contaminated with Blackhead the intensive system is commonly adopted. This entails the use of a brooder house with wire floor and a sun-parlour attached.

BUILDINGS FOR THE SMALL FARM

In the years between the two great wars, *i.e.*, between 1919 and 1939, the demand for small holdings resulted in the division of large farms into small units of from 5 to 50 acres, some of which may be under private ownership, some connected with county councils, and yet others under the aegis of land settlement associations and similar organisations. The occupiers of small holdings engage in one or other of the various forms of horticultural and agricultural enterprise, including dairying, calf rearing, and pig and poultry keeping. All the essential principles for farm buildings in general apply to the small agricultural holding, although there may be certain peculiarities and special difficulties in application. In the planning of new steadings for such holdings, however, great importance should be attached to securing a layout and form of buildings which are both adaptable and labour-saving. Adaptability to forms of husbandry other than that for which they were originally intended is even more necessary than on larger farms, for on the small holding the buildings must inevitably be fewer but their uses over a period of years may be no less varying. This means that the construction of specialised buildings like permanent cowsheds or stables should as far as possible be avoided. In place of the former, for example, consideration should be given to the yarding of milking cows together with the installation of a small fixed or movable milking parlour, while the place of the latter might be taken by a general purpose loose box provided with a suitable, but adaptable, manger and fittings ; if not required for a horse the loose box could readily be used for other stock.

Figs. 97 and 98 illustrate the general layout of the steading for a typical small holding engaged in milk production, but in which the
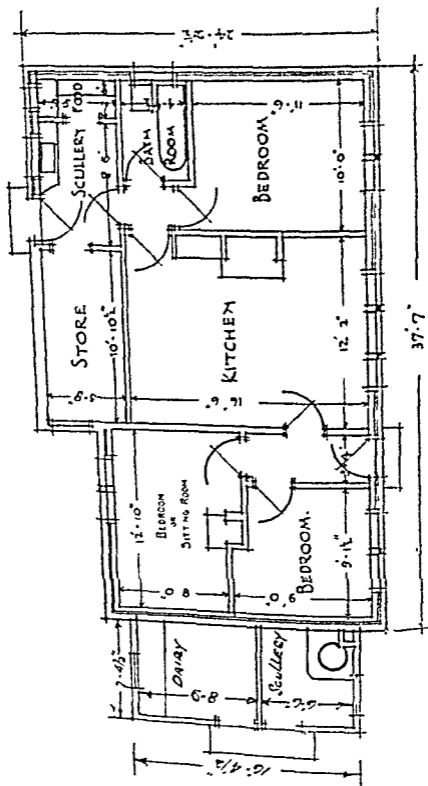
Fig. 98.—Plan showing the House of a Small Farm with the Dairy and Dairy Scullery attached. It is to be noted that there is no direct communication between the House and the Dairy, nor between the Dairy and the Scullery.

removal and alteration of internal partitions and fittings could easily be adapted to meet changes in the type of enterprise. It will be noted that accommodation is provided for four cows only in the "milking shed." With this number of cattle the shed can also be used for housing, as well as for milking, the cows, but if more are kept, they could be milked in relays, use being made of a system of open shedding and/or other suitable cover to accommodate them at other times, which, if not required for cows, could be used for the housing of other stock.

. The dairy, together with adjoining scullery in which the milk utensils are washed out and sterilized, is attached to the dwelling house rather than to the cowshed. (See Fig. 98.) It should be noted that there is no direct communication between dairy and scullery or between these and the dwelling house.

THE RECONSTRUCTION OF INSANITARY FARM BUILDINGS

. Animal houses may be condemned as insanitary for a variety of reasons. If in a city, it may be that their location is undesirable owing to their contiguity to human dwellings, together with their general insanitary condition. Reconstruction in such situations is often impossible and the buildings have to be vacated. The majority of farm buildings in country districts, however, are capable of being rendered sanitary and suitable for accommodating livestock, by reasonable structural alterations.

The common faults to be found in old cowsheds and stables include insufficient air space, lack of ventilation and light, underground drainage and/or the presence of gully traps within the buildings, insanitary and worn floors, narrow and low doorways, dampness, draughtiness, bad proportion of stalls and standings, too narrow passages, rough walls and partitions, complicated roof-trusses, in addition to many other less important defects. A badly-constructed dung pit or one too close to an animal house or to a milk store are common faults in the planning of layout.

While the Ministry of Agriculture takes an active interest in the condition of dairy cowsheds,* the housing of horses and other animals receives little or no attention, provided that a public nuisance is not caused. Complaints on this score are usually limited to the condition of the dung pit, or in towns to the length of time that manure is stored on the premises. The best type of animal owner, however, now takes an informed interest in the relation between the environment and health and productivity of his livestock, and usually carries out any

* See *The Milk and Dairies Regulations*, 1949.
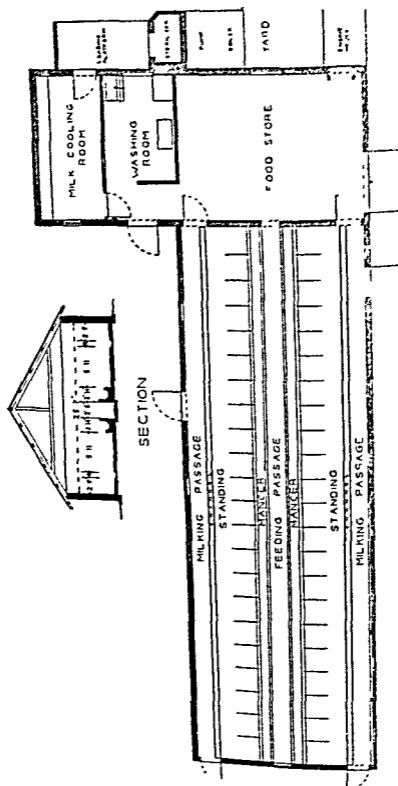
FIG. 99.—An old cowshed and auxiliary buildings before reconstruction.

MILK COOLING ROOM

WASHING ROOM

FOOD STORE

YARD

SECTION

MILKING PASSAGE

STANDING

MANGER

FEEDING PASSAGE

MANGER

STANDING

MILKING PASSAGE
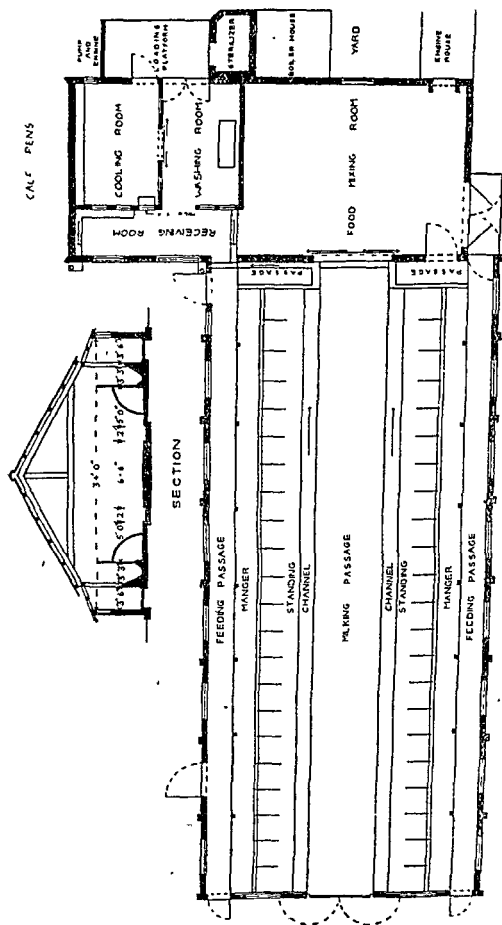
FIG. 100.—The buildings shown in Fig. 99 after reconstruction.

necessary improvements in their surroundings without any prompting from sanitary or other public health officials

Where structural alterations and general improvement is contemplated, a careful survey of the whole premises must be made so that the reconstruction may be done to the greatest advantage and with the least expense. No alteration or improvements should be recommended without there being sufficient reason, and the more important alterations must first be given consideration. Plans of the buildings should be prepared with all the proposed alterations shown thereon. Due attention must also be given to the relation of one building with another, and to the effects the alterations may have, not only on the health of the animals, but also on the labour involved in tending them. The details and methods of structural alterations, together with the supervision of the building practice, call for the services of a professional architect, experienced in farm building work and who, in consultation with the veterinary surgeon concerned, will be able to prepare a satisfactory scheme

Air space —Probably the most common of all defects in existing animal buildings, and usually the most difficult to remedy, is lack of sufficient air space for the animals the building is intended to hold. As a rule this is caused by the passage behind the animals having been made too narrow, i.e., the building itself is not sufficiently wide. This fault may sometimes be remedied by pulling down a portion of the walls, which will, of course, involve an extension of the roof

The simplest method of extension is to remove portions of the wall on the manger side of the building; new posts are inserted on the old foundations to carry the roof, and then the whole of the existing wall is taken down and the new wall of the extension built. Figs 99 and 100 show an example of the conversion on these lines of an old cowshed into a modern one which complies with the requirements of the Milk and Dairies Regulations, 1949

Net air space may, of course, be increased by excluding one or more animals from the building, but this will not give as satisfactory air exchange as would be the case if the building were designed on proper lines

It would be well to appreciate, however, that provided a building is structurally sound and well designed for its purpose, it would be folly to condemn it simply because the air space is a little less than what is held to be desirable. In many instances it will be found that the ventilation also is inadequate and, if this is corrected—a simpler and far more important matter than total air space—the building can usually be regarded as satisfactory

Occasionally it may be found that air space may be augmented by

heightening the walls. This, of course, would not be practicable unless the roof is so faulty that it needs rebuilding. It should also be remembered that the height of the walls must not be so increased that ventilation becomes faulty (see section on "Ventilation") ; a height of eight or nine feet should be regarded as the maximum desirable for any open-roof animal habitation.

Ventilation and Lighting.—In many old buildings the ventilation is deficient. As has already been mentioned, recent work suggests that provided outlets are satisfactory ventilation may be adequate even though the inlets are not in accordance with the standards usually recommended. Whenever possible, provision should be made for the outlet of stale air at the ridge. If new inlets are considered desirable then 4" sanitary bends may be inserted in the front wall or, particularly where the lighting is also deficient, new hopper windows may be installed.

Floors.—The flooring in many cowsheds and stables is very bad. Often it is composed of soft building bricks or paving slabs which have worn unevenly, or of concrete with a slippery surface (see "Floors," p. 179). In country districts the earth is sometimes the only flooring for stables, which should, of course, always be condemned.

In the preparation for relaying floors, the old floors should be entirely lifted, as patching never pays in any sense. After the old flooring has been removed, the top layer of the soil, which will be found sodden with urine, etc., must be lifted and a foundation made up with clean, broken stones to the required level. For the method of laying, and types of floors recommended, see the section on *"Floors."* When renovating a floor an effort should be made to fill up and round off all corners with cement.

Walls.—Apart from any necessary heightening it will be found that in the majority of old buildings the walls have been left in a rough state inside the building. They will then require to be finished off smooth with cement or covered with tiles to give the necessary smooth, hard face, that can be cleaned easily and which will not lodge dirt and dust. All wallheads inside byres and stables should be beam filled, *i.e.,* built up close to the roof boarding, thereby disposing of that troublesome shelf or scarcement on which dust and dirt accumulate, and which is so attractive to birds and vermin. Where the walls are to be cement plastered, the surface and jointing of the old work should be picked out thoroughly, cleaned, brushed over with a wire brush and properly washed before the application of the cement plaster. The joints on the outer surfaces of walls should be raked out and re-pointed, and all cracks repaired to prevent the entry of rain and frost. Walls which become saturated by reason of faulty pointing are liable

The site should be carefully chosen, consideration being given to the nature of the sub-soil, facility for drainage, water supply, etc. The location should preferably be away from dwelling-houses lest objection be raised on account of the noise made by barking animals.
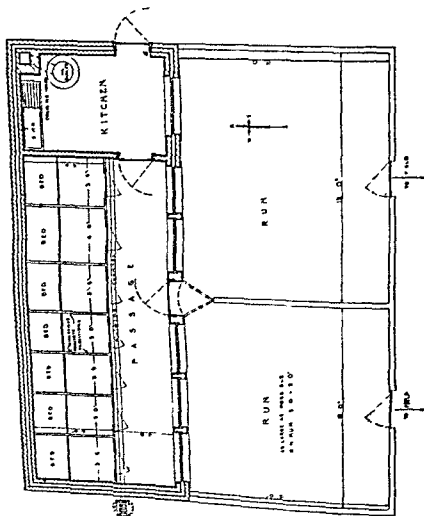
FIG. 102.—Plan of Dog Kennels arranged in a single row. Only seven kennels are shown, but the building would naturally be continued to a greater length.

Irrespective of the purpose for which kennels are required, the lay-out consists of substantial brick buildings where the animals eat and sleep, contiguous cement floored runs, which in turn communicate with a large exercising field; the latter is undoubtedly a great asset.

Where a large number of dogs are to be catered for, and in order to facilitate control of disease and noise, not more than 10 to 12 dogs should be housed in one building. This applies particularly to boarding kennels and infirmaries where the dogs are constantly changed and the risks of infection consequently greater than where the inhabitants are more or less static. A large infirmary would require separate blocks as follows :—

Reception, where animals are retained until a definite diagnosis is made ; this is very important, especially if distemper is suspected. If it is possible to have two or three reception places each consisting of two or three kennels, this is obviously a great advantage.

Distemper and Mange, each of which must be strictly isolated from the other, as well as from the other blocks.

Serious cases, surgical, whelping, etc., where quietness is essential.

Quarantine for the detention and observation of dogs from abroad. (See *Rabies Legislation*.)

Bitches in heat.—These cases must be kennelled separately and are best kept apart at all times.

In addition to kennels and exercising grounds, store rooms and kitchen with boiler are essential for the storage and preparation of food. A bath and dressing-room is also necessary in kennels of any size.

Arrangement of the Kennels in the Building. Kennels are usually constructed in a single-storey building but where ground space is lmited, as in a town, a double-storey building may be used. (See Fig. 101.) While the runs of upper-storeyed kennels must usually, of necessity, be small they may serve the purpose very well in the case of an infirmary, either for isolation, or for cases where little exercise is required.

The best arrangement of kennelling is the single row system with a southern aspect as shown in Fig. 102, although kennels may also be constructed against both walls of the building, with the dogs facing one another ; this latter arrangement requires a south-east and north-west aspect.

Walls.—These need not be more than 8 feet to the eaves, but if the house is a lean-to, a foot higher is desirable. The pitch of the roof will depend upon the width of the building and on the covering material used. The walls must be given an absolutely smooth face with cement containing a waterproof material, which should extend to a height of at least 5 feet from the ground. For the sake of appearance, and where cost is a secondary consideration, enamelled bricks or wall tiling may be used instead of cement. The upper portion of the wall
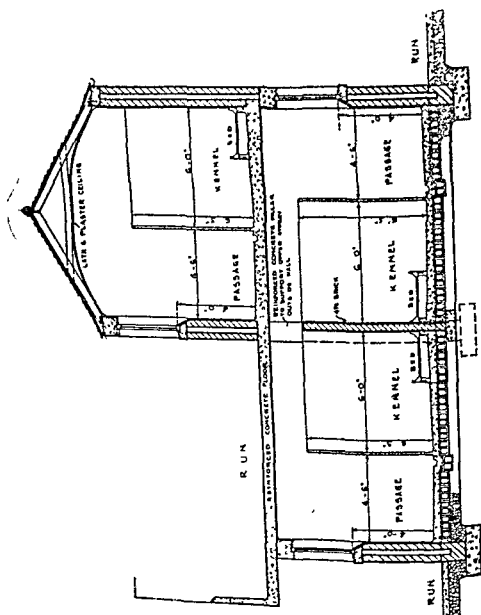
FIG. 101.—Section of a double-storey building with kennels placed back to back on the ground floor.

to disintegration and bursting with each severe frost. The internal surfaces of timber framed walls can be much improved by fixing expanded metal lathing to the uprights and covering it with cement plaster, trowelled to a smooth finish which can easily be washed down when necessary.

Drainage.—Defective drainage is a common fault. Underground drains are still met with in the older stables. In cowsheds the underground system is uncommon, but a gully trap is often placed inside the building at the end of the dung channel. In every case underground drains and inside traps should be removed and a surface method of draining, as advocated in the section on "Drainage," installed. Surface drainage in cow-sheds or stables may be faulty owing to wrong construction in the first instance, or to subsequent wear and tear. In stables laid with granite setts or cobble stones the drainage cannot be good as the urine invariably collects in little pools and gradually soaks into the ground between the stones or bricks. It is impossible to get good drainage without a properly laid floor, and when this is provided the drainage becomes a very simple matter.

Manure Pits are often badly placed on farms. The pit should be reconstructed as far away from the main farm buildings as is conveniently possible and in accordance with the principles laid down on page 96.

HOUSING OF DOGS

The buildings described below are designed on the assumption that the intention is to keep at least twenty dogs, and will be found suitable for a boarding establishment infirmary, or for racing greyhounds, pedigree studs, etc.

Kennels specially erected for any of the above purposes are usually designed to hold a considerable number of animals, and as they are usually intended to be financially remunerative, great care should be taken with their design and construction in order that the dogs can be kept in a healthy condition, and that the labour in looking after them is not excessive.

When planning buildings of this nature the general principles applicable to the construction of all animal habitations must be kept in mind. These are :—dryness, good drainage, adequate light and ventilation, warmth, comfort and cleanliness ; to these may be added ready accessibility to the dogs in their individual cages and safety measures to ensure that the dogs cannot escape from the kennels or injure themselves.

should be faced with plaster, and there should also be a lath and plaster ceiling, applied to eliminate all corners and to cover up as much woodwork as possible

The Floor should be made of cement and finished as smooth as possible   At the junction of the walls with the floor or with partitions and floor, all the angles so formed and all corners must be filled in with cement to a distance of 3 inches from the corner angle   This filling must be done at the time the floor is laid and not added as an afterthought

Drainage —The floor of the kennel and passages should have a fall of at least 1 in 50, sloping to a 4-inch channel in the passage, a few inches from the gates

Partitions between the cages are best made of 2 inch lightly reinforced concrete, smoothly finished, or of pre-cast slabs rendered in cement to a smooth finish   Less suitable materials are galvanised iron, either flat or corrugated, enamelled iron, or enamelled bricks   It is advisable to carry the partitions between the kennels right to the roof   Some people prefer to have them solid for the lower 3 feet only, the upper part being in the form of an iron grille   With an open grille, however, the inmates of the kennels are liable to annoy each other and to make constant disturbance by barking   If the kennels are intended for the housing of sick dogs then complete separation is best

Lighting —Kennels must be efficiently lighted and, where possible, metal framed windows should be used   Windows should not communicate directly with the kennel but with the passageways, where they are more conveniently controlled, and where there is no chance of injury to the dog or of escape   With some types of kennels, *e g*, where the dogs are face to face with a central passage, roof lighting may be used

Individual cages should be large enough for the inmates to move about with comfort   They should also be high enough for an attendant to enter and stand upright   As dogs differ greatly in size, space is saved if there is some variation in the width of the kennels , the height and depth (from front to back) should be the same in all cases, the height being approximately 6 feet and the depth up to 6 feet   The larger kennels, which may house two dogs, need not be wider than 4 feet 6 inches, while the smallest should not be less than 3 feet in width   The passage should not be less than 4 feet 3 inches, with a single row type of kennel (Fig 102), but where the kennels are arranged along opposite walls the central passage should be at least 6 feet 6 inches wide

Cement tends to be too cold and damp for dogs, and it is therefore desirable to provide an unslatted wooden platform and bedding for

them to lie on. This should be of ¾-inch hardwood ; an open slatted platform is very difficult to clean and is not so comfortable as solid wood. The platform should be raised 6 inches from the floor and occupy the width of the kennel and be at least 2 feet 6 inches deep. It should be movable and should be supported by four projections made of concrete, or on iron rests placed *in situ* when partitions are being cast. On the front or free edge the platform should have a 4-inch board above its level, and a similar one below the level, the former to keep the bedding in place and the latter to prevent a puppy or small dog from crawling underneath. These boards and all other wooden parts which could be gnawed should be covered with galvanised iron, the sharp edges of which must be turned under before being nailed down.

The front of kennels, including door, is made of iron rods at least ⅜-inch diameter. They should be placed not more than 1½ inches apart to a height of 3 feet 6 inches from the ground and 4 inches apart above that. The framework of the doors and the front may be made of angle iron, flat iron, or iron tubing. Tubular metal is very satisfactory provided the collars and junctions are sufficiently strong.

Doors are sometimes made with a diagonal strengthening rod. If the frame is properly made there is no necessity for this, and it is objectionable, because when the dogs claw at the door when people are passing nails get jambed between the diagonal and vertical rods with the result that they get torn off. A detail of great practical importance is to have the door hung so that the bottom is about 1½ inches from the floor. There are two reasons for this, one being that when the dogs are put into kennels they frequently try to run out as soon as they are released with the result that the door is shut quickly and the front paws of the animal may get caught and badly bruised ; the second reason is that a door hung clear of the cement floor does not soil or rust so readily.

A door 2 feet or 2 feet 3 inches wide will be found generally suitable. The door, which should be hung on three strong hinges and open out, should close against two rubber stops. The fastening of the door is very important. Self-fastening catches or easily closed doors are a mistake, because when an attendant is in a hurry he is inclined to swing the door, anticipating that it will shut and fasten ; *this it may fail to do* with the result the dog escapes. The only satisfactory door is one that the attendant has to secure himself and which he knows he cannot leave until it is secured. A bolt will serve the purpose and ought to be proof against carelessness. An S-fastening attached to the bolt by a short length of chain provides additional

security, and whilst not essential for ordinary kennels it should always be fitted to quarantine kennels

The ironwork is best galvanised, but if paint is used both the priming and the finishing coats must be of non-poisonous material

Water and Food Bowls—Ordinary non capsizable bowls made of enamelled ware are the most suitable for all purposes Fixtures for either water or food in the kennels cannot be removed for cleaning and are, therefore, entirely unsuitable for sick kennels or where the occupants of the kennels change frequently

Exercising Runs—Exercising runs form an essential part of dog kennels, not only to allow the dogs a limited amount of exercise, but also for the purpose of letting them out of their cages to defecate and to micturate Most dogs will not perform these functions in their cages and should be let out three times a day, in the early morning, at mid day, and last thing in the evening It is best to allow the dogs out separately in the exercising runs, but this is not always possible when the number of runs is small in proportion to the number of dogs which have to be exercised When two or three dogs are allowed to run out together, an attendant should always be at hand to intervene should fighting start A large number of dogs should never be permitted in the exercising runs at one time Under no circumstances should greyhounds ever be allowed to run with toy and similar breeds of dog

The floor of the exercising run must be of material that can be easily and thoroughly cleaned , concrete finished with a smooth surface is the most suitable material If the run is on the top floor, then it is necessary to make the surface waterproof by mixing a waterproofing liquid with the concrete, otherwise urine would soak through to the roof beneath The floor, which requires washing frequently, should have a good slope for drainage to an outlet In some convenient place away from the walls (the centre of the run is a good position) an urinating post of cement may be erected The corners of the run should be rounded off to facilitate cleaning

The walls surrounding the run need not be higher than 3 feet, i e, sufficiently high to prevent dogs urinating over them On top of the walls a surrounding fence of heavy galvanised interwoven iron netting will be quite satisfactory and less costly than continuing the wall upwards The wire fence must be 4 feet high thus giving a total height of 7 feet , at the top an in-turn of 1 foot is advisable to prevent dogs from jumping over the fence The framework of the fencing requires to be substantial, tubular iron being very suitable Runs may be constructed of wire and tubular iron framework without a supporting wall, in which case the wire should be placed on top of a 6-inch con-

crete foundation to prevent urine and faeces from escaping underneath and so as to preserve the wire.

The posts of the framework should be cemented at least 3 feet into the ground, the corner- and door-posts having diagonal supports also sunk 3 feet in the ground.

Heating.—An even warm temperature (approximately 60°F.) should be maintained in the kennels of an infirmary or in houses where breeding bitches or young puppies are kept. In small rooms electric heaters are satisfactory if they are kept burning at all times during cold weather. In large rooms some form of central heating is necessary. A slow combustion stove gives excellent results if it is properly stoked ; it is cheap, easy to erect and simple to look after. To get the best results from a stove, the outlet pipe should not go vertically through the roof as this wastes a lot of heat, but should be taken diagonally across the room before passing through the roof ; this also ensures better distribution of heat throughout the room.

Breeding Kennels. Figure 103 shows details of a building which has been found suitable as a whelping and puppy kennel. Bitches are housed in this kennel as soon as they are served or, at the latest, when confirmed as pregnant. They are removed after the puppies are weaned. Puppies may be reared here until they are removed for individual training. The number of puppies occupying a kennel is regulated according to their size and age. Any breeding kennel should always have a southern aspect. While the partitions between the individual kennels are the same as those described above, the front is solid for 3 feet from the ground, the remaining 3 feet 3 inches being iron grille. The kennel is 6 feet wide by 5 feet deep and has a door communicating with a passage 4 feet 6 inches wide on one side and on the other a small door about 3 feet high and 1 foot wide leading into a concrete floored run where the dogs may exercise at will. The runs should be at least 20 feet long, the width being varied to suit the number in the litter and the age and size of the puppies. At the northern end of these runs it is an advantage to have a shelter to break the wind. Beds for whelping bitches and for young puppies consist of a fairly large platform, with a 4-inch retaining board round it, raised from the ground by two crossbars, 1 inch high, nailed on the bottom of the bed.

Single Out-of-Door Kennels. Watch-dogs, terriers and sporting dogs are often housed in individual wooden kennels out-of-doors. Such a kennel must be large enough to hold the dog comfortably. It should be divided into two parts, a sleeping portion and an ante-room or

"verandah," the object of the latter being to keep the inner part dry and warm by preventing rain and wind from driving into it. The wood used in its construction must be strong and well seasoned so that it will not shrink and thus gape at the joints The top of the kennel
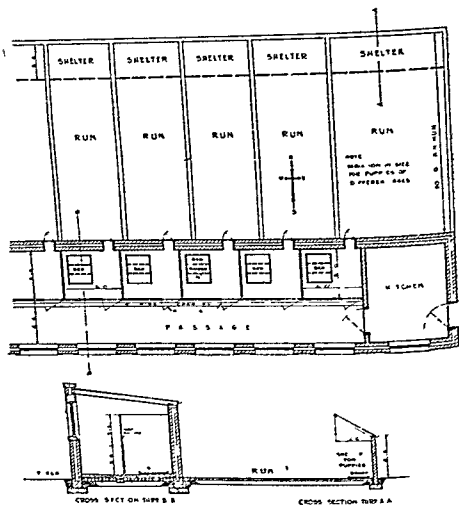
Fig 103 —Plan and Section of Breeding Kennels.

must be sloped so as to carry off rain quickly, and should be covered with felt or other suitable roofing material The framework of the kennel should not rest on the ground but should be supported by four corner legs about 3 inches high standing on slates

Instead of tying the dog by a short length of chain to the kennel it is more humane to have a light chain lead, fitted with a swivel at each end, running along a taut wire fixed between two points on the wall at the side of the kennel. For still greater freedom of movement

the wire may be fixed between two trees or posts, in which case stops must be placed on the wire to prevent the dog twisting the lead round the tree or post (see Fig. 104) ; the distance between post and stop must be greater than the length of the lead from collar to wire. It is important to keep the wire taut. The wire should be placed at the shoulder level of the dog and may be about 20 to 30 feet in length. Gauges 8 for large, and 12 for small breeds, are recommended.
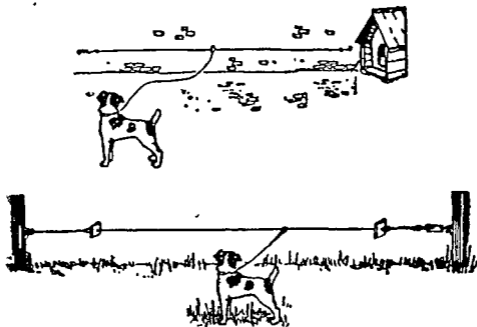
FIG. 104.—Illustrating the exercising chain described in the text.

THE CONTROL OF THE CONTAGIOUS DISEASES OF ANIMALS

A CONTAGIOUS disease is one caused by a specific agent (bacterium, filterable virus, protozoan or metazoan parasite) which may be transmitted from diseased to healthy individuals by direct or indirect contact. The common routes through which infectious agents may gain entrance to the body are by ingestion and inhalation, and by inoculation through the skin. Once established in the body of a susceptible animal, such an agent attacks and multiplies in the tissues, thus setting up a disease process. Quantities of the disease-producing agent come to be eliminated in the excretions of the affected animal, with the result that its immediate surroundings become contaminated and so constitute a source from which healthy animals may become infected. It is of considerable importance to realise that the ability of an infectious agent to survive outside the animal body for a longer or shorter time determines to a large extent its disease-spreading power, and also influences greatly the kind of measures which must be adopted to combat the disease.

Infection is transmitted from the diseased to the healthy in a variety of ways. Direct contact of a susceptible with an infected animal or with infective material is the most obvious, but not necessarily the most common, method of spreading disease. In many cases, human beings may convey infective material on their hands, clothing or boots to the surroundings of susceptible animals which may then become infected through contact with that material. Other animals, as well as vermin, birds, flies and biting insects, may also act as passive disseminators of infection. Foodstuffs and water supplies have been incriminated as factors responsible for the spread of disease though these are more frequent sources of infection in human beings than in animals.

In addition, certain diseases may be disseminated by the "carrier" animal, i.e., an animal that carries an infective agent within its body without exhibiting symptoms of disease. The infective agent may be eliminated intermittently in the excreta, etc., and so act as a source of infection to other animals ; or the infection may be conveyed from a carrier to a susceptible animal through the bite of an insect.

· METHODS FOR THE CONTROL OF DISEASE

The application of suitable measures for the prevention and eradication of any infectious disease must be based on a knowledge of the nature and properties of the causal agent, the way in which it is eliminated from the body of the diseased animal, and the means by which it normally reaches susceptible animals   In cases where the exact nature of the disease and its causal organism are unknown the steps taken will be in accordance with the severity of the disease and the symptoms displayed

The measures which may be adopted in attempting to control contagious disease are as follows —

   (1) Isolation of infected and in-contact animals
   (2) Slaughter of infected animals
   (3) Immunization
   (4) Interference with the life history of the causal agent or with the course of the disease
   (5) When the disease is communicable to man or is one which, if allowed to spread unchecked, would result in very considerable economic loss it is desirable that such control measures as are necessary should be carried out under the direction of a central authority   The primary measure in the control of such a disease will be notification of its existence or suspected existence

Isolation.   Animals which are known to be, or suspected to be, affected with a contagious disease must be isolated from the apparently healthy.

Whilst lack of suitable accommodation may hinder the application of strict isolation every effort should be made to see that the segregation is as complete as possible and that it is undertaken without any loss of time   A separate building is desirable, but if such premises are not available then the animals concerned should be placed in one section or at one end of the building as far away from the healthy stock as practicable

Separate buckets, rugs, grooming tools, etc , must be provided for the isolated animals and, if possible, a separate attendant who is not permitted to go near the healthy   If this cannot be so and the same man must have charge of both sick and healthy then he must attend to the healthy first and then to the sick   He should be provided with special overalls to be worn only when working among the isolated animals and with rubber boots which, together with his hands, can be easily disinfected on leaving the isolation unit ·

The period of isolation must extend beyond recovery of the animals and not be ended until all possibility of infection has passed   The time

limit varies with different diseases and may be difficult to determine but it is better to err on the side of caution than to return an animal prematurely to association with the healthy. Undue haste in this respect may undo all the good derived from previous care and labour.

Quarantine. Quarantine means the segregation of apparently healthy animals which have been exposed to risk of infection from those animals which are healthy and have not been exposed to the risk of infection. The object of this is to give time for a contagious disease that may be in the latent phase to become active and obvious. Since the period of incubation of different contagious diseases varies considerably, a specific quarantine period that gives a margin of safety is allowed for each. The incubation period of rabies, for example, may extend to six months and a long quarantine period is necessary. On the other hand the quarantine period prescribed for foot-and-mouth disease need only be a fortnight or so as its incubative period is short.

Slaughter of Infected Animals. When a disease is highly contagious and is liable to spread with great rapidity, e.g., foot-and-mouth disease, slaughter of affected animals and those which have been in immediate contact with them is necessary. The carcases must be disposed of either by burial or by burning (see page 322).

Slaughter of diseased animals which constitute a potential source of danger to the human population, e.g., "open" cases of tuberculosis, is also essential.

Immunization may be practised when the incidence of the disease is so high, or the reservoirs of infection are so extensive, that control by segregation or slaughter alone is impracticable. It would obviously be an impossibility to eradicate completely diseases caused by organisms which can live for indefinite periods outside the animal body and still retain a high degree of virulence ; examples of diseases in this category are anthrax, blackleg, lamb dysentery and swine erysipelas. Immunization may, therefore, be undertaken in these diseases with the object of building up an animal population highly resistant to infection. This method is also adopted with diseases where the incidence of infection is so high and the routes of spread so complex that it is uneconomic or impracticable to adopt a slaughter or segregation policy, e.g. swine fever in the U.S.A. and brucellosis of cattle.

Immunization must never be regarded as a substitute for sanitary measures. When it is practised strict isolation, and in some cases slaughter, of affected animals is still necessary and the need for

adequate disinfection must still be stressed   For details of the methods
of immunization available in different diseases the reader is referred
to textbooks of veterinary medicine

Interference with the life history of the causal agent or with the
course of the disease includes such procedures as disinfection and dis-
infestation, treatment of sick animals, and measures aimed at the
elimination of carrier animals and intermediate hosts if such exist
With most animal diseases the application of the procedures included
under this heading is complementary to the other methods of control

From what has already been said it will be evident that there are
many obstacles to be surmounted in attempting the control of animal
diseases, among the more important being , the ability of some disease-
producing agents to retain their infectivity for relatively long periods
outside the animal body and their comparative resistance to chemical
and other disinfectants , the existence of carrier animals in the case
of certain diseases which may disseminate infection without giving any
indication of the fact until the disease has become more or less wide-
spread , the constant and wide traffic in animals which favours the
spread of infectious maladies and, at the same time, increases the diffi
culty of tracing and controlling the carriers of the infection , and the
indifference and carelessness with which some stockowners regard con-
tagious diseases and, with what may amount to criminal negligence,
fail to notify the presence of disease among their stock, or to take such
precautions as are incumbent upon them for the safeguarding of their
neighbours' animals

Notification   The official notification of certain contagious diseases
of animals is obligatory in Great Britain and the procedure involved
is dealt with later when considering these "scheduled diseases"
Danger to the life of animals or of man is not the only reason why
certain diseases have been selected for legislative measures Some
diseases, such as sheep scab or swine fever, would cause widespread
trouble and great financial loss if left unchecked, or only subjected to
spasmodic or partial supervision Foot-and-mouth disease is an instance
where, if the disease were allowed to rage unchecked, whilst the death
rate might be low, the financial loss to the country as a whole would
be incalculable, due to loss of milk, loss of condition and to abortion

Notification of the existence or suspected existence of a scheduled
disease serves the following purposes —It informs the central authority
of the existence, or suspected existence, of the disease and its location
It brings experts into contact with the disease, and enables them to
confirm or refute the suspicion.   It puts into operation control measures

such as the slaughter or isolation of infected animals and the quarantine or slaughter of in-contacts, places restriction on the movement of animals within a specified area, and ensures the proper disinfection of contaminated premises and materials. It enables the authorities concerned to ascertain the origin of the disease, and to trace other animals that may be infected and may be acting as new centres for the spread of infection. In the case of a disease such as anthrax, if several deaths have occurred in different localities, at or about the same time, it may be possible to find evidence pointing to a common source of infection such as one particular consignment of imported foodstuff being contaminated with anthrax spores. Under such circumstances the destruction or sterilisation of all unconsumed stores of the foodstuff in question would prevent further outbreaks.

Compulsory notification draws attention to the presence of the disease and enables stock-owners to adopt preventive measures against introducing infection into their own herds and flocks. It is of great value in "inculcating watchfulness upon the general practitioner, and suggesting the need for a definite diagnosis in doubtful cases" (Lewis and Balfour).

Local authorities have the power to advertise in the local press, to post notices in public places, and to placard the infected premises. Public notification of the existence of an infectious disease is of undoubted value, but care should be taken to avoid causing undue alarm. With the information to the public that a specific and infectious disease exists among stock, or is likely to appear owing to its proximity in another district, advice should be given to stock-owners by competent persons as to the best methods to be adopted to keep their premises and animals clear of infection. Unnecessary traffic among neighbouring farms or stables should be avoided, premises should be kept clean, animals should be well attended to ; they should be well fed and not over-worked. Notification gives information of the extent of any particular disease in the country, or part of the country, so that the authorities concerned with its control may know if the incidence is on the increase or decrease, and consequently whether to relax or to make more stringent their regulations.

For the greatest advantage to be obtained from notification it must be done at the earliest moment. Any delay or hesitation gives time for the infection to become more widely disseminated among susceptible animals. Some diseases are not easily diagnosed and may at times appear in atypical forms, whilst others, e.g., rabies, appear so rarely in this country that the general public, and even the practising veterinary surgeon, might not recognise the diseases from their imperfect acquaintance with them. When there is any suspicion that

a notifiable disease is present, the onus of the responsibility of deciding whether or not it exists should be put upon the experts whose business it is to make the decision. If, after notification has been made the suspicion turns out to be unfounded, then no harm has been done, unless undue alarm has been raised. If, on the other hand, there has been any delay in reporting the suspected existence of a disease such as foot and mouth disease and it is actually present, then the results may be very serious

DISINFECTION

Disinfection means the conversion of a place, or object, from a potentially infective state into one which is free from infection. This implies the destruction of pathogenic micro-organisms and their spores. Many substances are able to destroy bacteria when used in a sufficiently concentrated form, but the designation *disinfectant* or *germicide* is generally applied to substances which are able to exert a lethal action in high dilution on micro-organisms and their spores. Many disinfectants are rendered inactive or their power to destroy organisms may be considerably reduced by the presence of organic matter. *Cleansing,* therefore is an essential preliminary to disinfection

An *antiseptic* is, strictly speaking, an agent that inhibits bacterial growth, but the term "antiseptic" is frequently employed as synonymous with disinfectant, since most substances that retard bacterial multiplication act as germicides if used in sufficient concentration

The Destruction of Micro-organisms by Natural Agencies. Many pathogenic micro-organisms do not survive for long outside the animal body. Some, however, under favourable conditions of temperature and moisture may remain alive for considerable periods, whilst the spores of such organisms as *Clostridium chauvoei, Bacillus anthracis,* etc, may live indefinitely in the soil. A number of factors contribute towards the destruction of the more susceptible organisms

Desiccation. Fresh air and wind dry up moist dirt that holds bacteria, and the more rapid the process of desiccation the more fatal it is to micro-organisms. Most non sporulating organisms can withstand only two to five days exposure to drying but others, the tubercle bacillus for example, may live for weeks and months

The spores of *B. anthracis* and *Cl. tetani* are very resistant to drying and may survive for many years whilst the oöcysts of coccidia may remain viable for a year or more. According to one author the oöcysts

of *Eimeria tenella*, the cause of caecal coccidiosis in poultry, can still be infective after eighteen months in the soil.

In their resistance to desiccation and other noxious agencies the filterable viruses vary considerably, but on the whole they resemble vegetative bacilli rather than bacterial spores. Epithelial scales from a case of foot-and-mouth disease have been found infective after exposure to winter conditions for sixty-seven days. In hay this virus remains viable for twenty-five to thirty days, but under exceptional circumstances it may survive for several months.

Direct Sunlight has a germicidal action in virtue of its ultra-violet rays and of the rays at the blue end of the spectrum, but the most highly bactericidal radiations, which have a wave-length of 2100-2960 Angström units,* never reach the surface of the earth even in very clear weather. The ultra-violet rays with a wave-length greater than 3000 A.U. reach the earth and have a definite bactericidal action while the visible rays of sunlight are not altogether devoid of germicidal power, though they take much longer to produce a lethal effect. For example, tubercle bacilli are destroyed in about two hours if exposed to the direct rays of the sun. On the other hand, the presence of small amounts of mucus or other organic material will protect the organisms from the effect of sunlight.

The efficiency of sunlight in destroying bacteria is proportional to the directness and intensity of the light. Ultra-violet rays have little penetrating power ; they do not pass through ordinary window glass, and sunlight transmitted through closed windows has not the same disinfectant power. Clouds and smoke reduce the effectiveness of light and penetration through water is greatly inhibited by suspended organic matter.

Temperature. The rate of bacterial destruction is more rapid under warm conditions than under cold. It has been shown that the reduction of the number of typhoid organisms in a sample of water from 100,000 to 3 per ml. required five weeks at 32°F., three weeks at 50°F. and only two weeks at 64°F.

The majority of bacteria both sporing and non-sporing resist freezing, and some bacteria are not destroyed even by extreme degrees of cold, *e.g.*, after exposure for several weeks in liquid air. Most viruses appear to be very resistant to cold and survive longer under winter conditions than in summer.

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* An Angstrom unit is equal to one ten-millionth of a millimetre, or one ten-thousandth of a micron (μ), the unit used in measuring the dimensions of bacteria. Retinal sensibility extends from 3970 A.U. (violet) to 7594 A.U. (red).

application of hot water, especially if it contains washing soda is, however, very useful owing to its cleansing action   A thorough scrubbing with hot soda water should be regarded as an essential adjunct to disinfection

The boiling of metal articles such as surgical instruments has long been a recognised method of effecting sterilization.   Rusting can be prevented by boiling the water for some time previous to the immersion of the articles or by the addition of 1 per cent. sodium carbonate   The addition of this salt to boiling water helps to remove grease and hastens the destruction of bacterial spores

Schroeder* has described a cleaning unit in use in the United States for the disinfection of animal hospitals and other livestock premises   The apparatus consists of a "steam jenny vapour spray unit" which (1) will deliver a stream of water at over 100 lbs pressure, (2) will deliver water at 60 70° C to the area being cleaned (over 100° C as the water leaves the nozzle) and (3) incorporates a detergent and disinfectant in the water stream in any desired concentration. A similar apparatus is now available in Great Britain

Steam. Steam is a much more effective sterilizing agent than hot air at the same temperature, and several factors are responsible for its greater activity   In the first place, it quickly raises the temperature of articles with which it comes in contact   In order to convert a certain quantity of water at 212° F into steam at the same temperature a definite amount of heat, the latent heat of vaporisation, must be supplied to the water   When the converse process occurs, i e , when steam comes into contact with a cool object, it condenses, and the latent heat of vaporisation is set free resulting in a rapid warming of the object   When steam is used as a disinfecting agent condensation occurs on the bacteria and spores and they are in consequence, quickly heated to the temperature of the steam

Secondly, the penetrating power of steam is much greater than that of hot air   This is due partly to its comparatively low specific gravity, which enables it to diffuse into porous materials and displace the contained air and partly to the fact that when saturated steam comes into contact with cool objects it condenses into water, which has only 1/1700th part of the volume of the steam   On coming in contact with, say, a bundle of rugs it warms and penetrates the outer layer, undergoes condensation and reduction in volume, with the formation of a partial vacuum   More steam rushes in to fill the area of reduced pressure, and this steam, diffusing further into the interior of the bundle, itself undergoes condensation   The process is repeated until

* Schroeder, C. R *Proc 52 Ann meet U.S Livestock San Assoc* 1948 Page 113

steam has reached the centre of the bundle. The great penetrating power of steam as compared with hot air is illustrated by an experiment conducted by Koch and Wolffhügel, in which a thermometer placed at the centre of a bundle of linen was surrounded by twenty layers of this material. After four hours' exposure in a hot-air chamber at 265-285° F. the temperature at the centre of the bundle was only 187° F. When the bundle was exposed to steam for three hours, the temperature of the steam gradually rising during this time from 194° F. to 221° F., the temperature attained in the centre of the bundle was 214° F. The great penetrating power and rapid sterilizing action of steam are obviously of great value in the disinfection by heat of bulky articles.

In all disinfection by steam, however, whether at atmospheric pressure or at greater pressure, the maximum germicidal affect is obtained when the steam has free access to the objects. Articles that are to be disinfected should therefore be arranged loosely so as to facilitate penetration by the steam.

In the third place, the greater efficiency of steam as compared with hot air at the same temperature may also depend on alterations in the coagulability of bacterial protein due to variations in the water content of the protoplasm. Bacteria exposed to moist heat may absorb water and their protein content become more readily coagulable, whereas micro-organisms exposed to dry heat undergo dehydration and their protein becomes proportionately less coagulable.

Disinfection by steam spoils leather and is likely to alter the colouring and texture of blankets. Cotton and linen fabrics stand steam and heat well, but bloodstains are fixed.

Current Steam is steam rising from water boiling at atmospheric pressure, *i.e.*, 15 lbs. per square inch.

In the sterilization of dairy utensils current steam is the agent of choice. The process is carried out in a large galvanised iron chest with a tightly fitting door. In the base of the chest there is a hole which allows for drainage and for the exit of air displaced by the steam. The steam pipe should enter low down at one side and the part inside the chest should be pierced with holes in such a way as to deliver steam in all directions except downwards. A metal rack, upon which the articles for sterilization are placed, is fixed a few inches above the steam pipe thus allowing for free circulation of the steam. An accurate thermometer placed so that it can be conveniently read, is essential. The steam may be generated in a separate coke-fired boiler or the whole unit may be self-contained with an electrically heated steam generator in the base.

—V.H. 21

Before sterilization all utensils must be thoroughly cleansed of milk residues by rinsing in cold water immediately after use and then scrubbing with a hot detergent solution   Milking machine buckets and other hollow vessels must always be placed in the sterilizer in an inverted position so that steam can enter freely and the contained air escape   If such articles are placed in the upright position pockets of air may form in them and sterilization may be imperfect   Steam is admitted to the chest gradually, allowing about twenty minutes for the chest and its contents to reach a temperature of 210°F   When this temperature has been attained steaming must continue for ten minutes at the end of which period the steam is turned off and the door of the chest is opened immediately   This avoids condensation and allows the residual heat in the utensils to evaporate any moisture remaining on them   When cooling has taken place the chest is closed again to prevent access of dust and flies to the clean articles

Churns may be sterilized in the chest or by inverting them on a special churn steaming jet for a few minutes   milking machine tubes and teat cup clusters may also be attached to special jets and the steam allowed to flow gently for two minutes after a temperature of 210°F has been attained   If the preliminary cleansing is carried out thoroughly the rubber parts of milking machines will withstand repeated steam sterilization for a considerable time   If, however, traces of milk fat have not been properly removed the rubber liners and tubes may soon require replacement.

Steam may also be used to free suspect straw from the virus of foot and mouth disease in cases where the straw is being imported into Australia, either in the form of manufactured goods or as packing. Straw which has been subjected to the action of steam at 185°F for at least ten minutes is regarded as disinfected and is admitted into the Commonwealth   This method of disinfection has the drawback that the straw is thereby rendered damp   (See page 318)

There are various steam disinfectors on the market, some fixed, such as are used by municipalities for the disinfection of clothing from infectious houses, and others that are portable or built on wheels for convenience of transport   Some of these disinfectors employ current steam, while others utilise steam under pressure   For the purpose of sterilization it is more advantageous to have a continual current of steam through the disinfector than merely to have the steam confined in the chamber   When steam is constantly flowing through the machine containing the articles to be disinfected it displaces and drives before it the air contained in the folds and interstices of clothing, etc The air is thus more quickly expelled and the penetration of the steam hastened   The period for which articles are subjected to the action

of the steam varies with the type of disinfector but is generally about twenty to thirty minutes.

Steam under Pressure. An increase in the pressure under which steam is generated can only be effected in an air-tight container. When water is boiled in a sealed vessel, which is necessarily fitted with a safety-valve and a pressure gauge, the steam accumulates and undergoes compression until the pressure inside the vessel reaches the point determined by the safety-valve. The temperature at which water boils depends on the pressure to which it is subjected ; the higher the pressure, the higher the boiling point, and the steam rising from the water remains saturated at the temperature of the boiling liquid. The pressures generally used in sterilization by steam vary from 5 to 15 lbs. per square inch above that of the atmosphere. At a pressure of 5 lbs. per square inch above atmospheric pressure water boils at 228°F. ; when the pressure is increased to 15 lbs. per square inch above atmospheric pressure the boiling point is approximately 250°F. Saturated steam at a pressure of 15 lbs. per square inch above normal atmospheric pressure is an extremely efficient sterilizing agent destroying all life within ten minutes.

In sterilization by steam under pressure it is very important to expel all the air from the disinfecting chamber or the efficiency of the steam is reduced. This is done by allowing steam to pass freely through the sterilizer for a few minutes before the valve is closed or, alternatively, by partially exhausting the air inside the chamber before admitting the steam. A temperature of 250°F. should not be exceeded or goods may be damaged by the heat.

Steam under pressure is in constant use for sterilization of infected material in bacteriological laboratories and hospitals, the method generally adopted being to subject the material to be sterilized to the action of saturated steam at 250°F. for twenty to thirty minutes in the autoclave.

CHEMICAL DISINFECTANTS

Whilst a large number of chemical compounds possess germicidal powers many are of little practical use as disinfectants owing to their toxicity, corrosive power or cost. The actual processes which occur during the destruction of bacteria by disinfectants are complex and imperfectly understood, but the injurious action of these substances on living organisms can frequently be attributed to definite types of reaction.

Oxidation, hydrolysis and the formation of salts with proteins are three common ways in which disinfectants are known to exert their effect Some may bring about a modification of the permeability of the bacterial envelope whilst others act by interference with the metabolism of the cell. Several different types of reaction may occur simultaneously

When the lethal action of a germicide on a bacterial population is studied it is found that many more bacteria are killed in a given period at the beginning of the process than towards the end Although there may be, with some disinfectants, a preliminary "period of lag," the majority of the organisms in the suspension are destroyed in quite a short time Complete sterilization however is effected only after a considerably longer period An examination of the number of organisms surviving at different stages during disinfection shows that the number of bacteria killed in unit time bears a constant relationship to the number of surviving organisms i e, the process of disinfection is of the nature of a monomolecular reaction A reaction of this kind is a special example of the Law of Mass Action and is illustrated by the interaction of solutions of two chemical substances where one reagent is present in such excess that alterations in its concentration may be disregarded and only the other reacting substance may be considered as undergoing change In the disinfecting process the disinfectant corresponds to the substance in excess while the bacterium is the reagent undergoing change The destruction of bacteria by a germicide is in this respect similar to a chemical reaction and other analogies may be discovered. Thus the process of disinfection is affected by changes in *temperature* in the same way as a chemical reaction being accelerated by an increase, and retarded by a fall, in temperature The extent to which the rate of disinfection is influenced by alterations in temperature varies with different types of germicide and different organisms Thus a rise of 10°C renders the action of phenol against *Staphylococcus aureus* about five times more rapid against the typhoid bacillus a similar rise makes phenol eight times more rapid The bactericidal action of hot water, however, is increased to a much greater extent the exact amount of the increase varying with different organisms For example a rise in temperature of 10°C involves a 12 fold increase in the rate of destruction of *B coli*, a 29 fold increase for the staphylococcus It has been shown that in the destruction of the foot and mouth virus by hot water, a rise of 10°C renders the process of disinfection 201 times as rapid Whenever possible disinfectants should be used in hot solutions

Change in the *concentration* of a disinfectant naturally involves a change in the rate of disinfection , the relationship between the two, however, is not one of simple proportion but an exponential (logarith-

mic) relationship, the value of the exponent, which is termed "n", varying for each disinfectant. For phenol the value of "n" is about 6, and doubling the concentration of phenol increases the rate of disinfection 2^6 or 64 times. Thus whilst a 1 per cent. solution of phenol is a relatively strong disinfectant and is capable of destroying typhoid organisms in a few minutes, a 0.5 per cent. solution is relatively feeble as a disinfectant its germicidal power being 64 times less than that of the 1 per cent. solution. For mercuric chloride the value of "n" is about unity and the germicidal value of this salt thus bears a direct relation to its concentration.

The presence of organic matter interferes with the action of all germicides, even a purely physical agent such as heat being rendered less effective when organic matter is present. There is a noticeable protective action when the organisms are contained in material which is particulate or viscous. Moreover, the organic matter may react with the germicide to form compounds which are less effective than the unaltered disinfectant, or it may have a neutralizing effect on the disinfectant, thus reducing substances present in water which is polluted with sewage may lessen considerably the effectiveness of chlorine as a germicide.

The pH of the solution influences the action of many disinfectants; for example, phenol and its relatives and the chlorine compounds are more active in acid than in alkaline solutions. The strong alkalies themselves are, however, powerful disinfectants.

Practical Application of Disinfectants. The conditions under which the various chemicals are used affect their potency to a very marked degree. All solutions of disinfectants should be made with clean water. Moderately soft water, that is water containing not more than 12 parts of calcium carbonate per 100,000, is much to be preferred to a hard water. This is especially important when the disinfectant has a cleansing action, as is the case with *Liquor Cresolis Saponatus* and similar preparations. In making a solution of a desired strength it is important that the quantities of water and of the disinfectant are accurately measured and not guessed. No other chemicals must be added than the one it is desired to use. The combination of two or more disinfectants, so far from increasing the potency of the solution, may bring about chemical reaction with the production of inert new substances. The vessel in which the solution is made must be clean, and the reagent used must be thoroughly mixed with the water and not merely added to it. In selecting a disinfectant careful thought should be given to the purpose for which it is to be used and its possible effects upon materials with which it will come into contact. The destructive

power of many agents must be borne in mind. Caustic soda, for instance, can be very harmful to both animals and human personnel if used inadvisedly; it also damages paintwork. Formaldehyde has a tanning or drying effect on leather and bleaching powder is destructive to harness and clothing if used too strong. The time factor is important, and a sufficient period must be allowed to elapse for the disinfectant to do its work.

Sodium Hydroxide (Caustic soda). For general use in farm buildings and animal houses caustic soda is a very satisfactory disinfectant in that it combines excellent cleansing properties with powerful germicidal action.

The gram-negative non-sporulating bacteria and the viruses are particularly susceptible to strong alkalies but spores and the acid-fast bacteria are more resistant. A 1 per cent. solution of commercial lye (94 per cent. NaOH) is generally employed. Its strength is somewhat reduced in the presence of organic matter, though not so much as in the case of many other agents, but a 2 per cent. solution will probably be effective even when large quantities of organic material are encountered. Against spores, a 5 per cent. solution may be used but particular caution must be taken to avoid contact with the skin as such a solution is very caustic.

Rubber gloves and protective clothing should always be worn when lye solutions are being used for disinfectant purposes and, if possible, the eyes should be protected with goggles.

Sodium Carbonate (Washing soda). Sodium carbonate is officially recommended by the Ministry of Agriculture and Fisheries for the disinfection of premises upon which outbreaks of foot-and-mouth disease have occurred. For this purpose a hot 4 per cent. solution is employed; this is approximately 6 oz. of washing soda to a gallon of water.

This solution has also been extensively used for the disinfection of poultry houses, etc., in outbreaks of fowl pest (Newcastle disease). Its effectiveness for this purpose has however been questioned (although its detergent powers are useful) and 2 per cent. sodium hydroxide or 1 per cent. lysol are more reliable agents for the destruction of the Newcastle disease virus. (* Cunningham, 1948.)

Bleaching Powder ("Chloride of lime," Chlorinated lime, Calx chlorinata). The exact chemical composition of bleaching powder, which is sold for disinfectant purposes as "chloride of lime," is not

known.   The formula $CaOCl_2$ is usually assigned to it.   The common commercial product often contains impurities, especially an excess of calcium chloride.   Bleaching powder is made by passing chlorine over slightly moist slaked lime, and is a dull white or greyish powder with a distinctive unpleasant smell.   It is moderately soluble in water (in about 20 parts).   The bactericidal activity of bleaching powder depends on the amount of "available chlorine" that it contains, and this should not be less than 30 per cent.   This amount is specified as the minimum when the powder is used as a disinfectant under the regulations of the Ministry of Agriculture.   Bleaching powder is unstable, and under the action of atmospheric CO_2 is liable to decompose, so that the available chlorine content is reduced ; if kept in damp surroundings and exposed to light and air, the decomposition is more rapid, it must therefore be stored in airtight tins.

The germicidal action of bleaching powder probably consists of a combination of oxidation and chlorination of the protoplasm of the bacterial cell.

Although powerful disinfectants the value of bleaching powder and of all the chlorine-containing disinfectants is limited by the fact that they are rapidly-inactivitated in the presence of organic matter.   The use of bleaching-powder as a disinfectant for animal houses when contagious disease has occurred is thus somewhat restricted, though it is a good deodorant and may be employed in the routine cleansing of stables.   As regards its use in cowsheds and dairies, there is the further disadvantage that it is liable to taint the milk.

Reference has already been made to the use of bleaching powder for the sterilization of water supplies (see page 33).

Sodium Hypochlorite. Like bleaching powder, sodium hypochlorite owes its germicidal power to a combination of chlorination and oxidation.   It is a powerful germicide in the absence of organic matter but if much albuminous material is present its efficiency is greatly reduced.   It deteriorates rapidly if stored improperly ; the salts of the metals and exposure to light or heat can soon bring about loss of active chlorine content.

The use of approved sodium hypochlorite solutions as an alternative to steam for the sterilization of dairy utensils is authorised under the Milk and Dairies Regulations, 1949.   Approved solutions must contain 9 to 12 per cent. of available chlorine, not less than 0.7 per cent. of sodium chlorate and not more than 2 per cent. of free alkali.   The "Chlorine-wash" recommended by the *Ministry of Agriculture and Fisheries* is made by adding 5 ozs. of the approved solution to 10 gallons of hot water (above 180 F.) together with 4 oz. of soda ash or

another detergent It should be noted that large quantities of alkaline detergents will reduce considerably the disinfectant power of the sodium hypochlorite After milking utensils have been rinsed in cold water they are thoroughly scrubbed in the hot chlorine-wash and then subsequently rinsed in a bath of "Chlorinated water" which is made by adding a large teaspoonful of the approved solution to 10 gallons of water

Sodium hypochlorite is also valuable in the cowshed in the preparation of the udder for milking and for the disinfecting of teat cups after removing them from one cow and before placing them on the next The solution used for this purpose is made by adding 2½ ozs of the approved solution to two gallons of clean water

Quicklime (Calcium oxide) Quicklime may be used as a disinfecting agent but it must be fresh to be effective If it is left exposed to the air it reacts with moisture and is converted into slaked lime which has little germicidal activity

The dressing with quicklime of land which has been contaminated with the organisms of contagious disease is frequently advocated but there is little evidence of its value in accelerating the destruction of pathogenic organisms under these conditions It is usually applied at the rate of two tons of quicklime to the acre When it is necessary to dispose of a diseased carcase by burial it should be covered with quicklime before the earth is thrown in, and any faeces, etc , should be thoroughly mixed with quicklime and buried with the carcase

Slaked Lime (Calcium hydroxide) The disinfectant value of the alkalies is dependent upon the concentration of free hydroxyl ions in solution, but as calcium hydroxide is only slightly soluble in water there is a relatively small number of dissociated hydroxyl ions and it has consequently little potency as a germicide Slaked lime, so-called "milk of lime," and whitewash, all of which contain calcium hydroxide, are thus of little value as disinfectants When whitewash is used on the walls of animal houses it is recommended that a disinfectant *e g ,* 1 per cent lysol be added but, when an outbreak of contagious disease has occurred, this must not be regarded as a substitute for a thorough cleansing and disinfection of the premises which must be carried out before the whitewash is applied

Ammonia. A 10 per cent aqueous solution of ammonia is the most effective agent for the destruction of coccidial oocysts Its use in poultry houses after outbreaks of coccidiosis is referred to on page 437.

Mercuric Chloride (Perchloride of mercury, Corrosive sublimate). Mercuric chloride is of little practical value as a disinfectant for veterinary purposes. Its early reputation as a powerful germicide in great dilutions was proved to be unfounded, its action being largely bacteriostatic and not bactericidal. Moreover, it is very toxic to man and animals, it has a corrosive action on metals, and such anti-bacterial powers as it possesses are rapidly diminished in the presence of protein-containing organic matter, the mercury being precipitated as the insoluble albuminate of mercury.

Phenol (Carbolic acid). Subsequent to its popularisation by Lister, phenol long held premier position as an antiseptic and disinfectant. Nowadays, however, for most practical purposes other agents are to be preferred, though phenol is still used as a standard in assaying the value of other germicides (see page 315).

In sufficient concentration phenol is effective against a wide range of organisms; most common bacteria are killed after five or ten minutes exposure to a 1 in 80 dilution at 30° C. Spores are more resistant and it has been shown that anthrax spores can survive very considerable exposure to 5 per cent. phenol. The viruses, too, show considerable resistance to its action.

Unlike many other disinfectants, phenol maintains its activity well in the presence of organic matter but oil or alcohol greatly reduces its disinfectant power. When used in aqueous solutions phenol acts as a protoplasmic poison, the intact molecule reacting with the bacterial protein to form insoluble albuminates, but when oil is present the phenol shows little tendency to combine with the protein of the bacteria. Increases in temperature enhance the anti-bacterial action of phenol but, as noted on page 309, slight dilution reduces its powers considerably. Other disadvantages of phenol as a disinfectant for veterinary purposes are that it is very toxic to man and animals and is irritant in germicidal concentrations, it is expensive compared with other more efficient agents, and its odour is readily absorbed by milk and other food products.

Crude carbolic acid consists of 95 to 97 per cent. of cresols and higher homologues with but little phenol. It is only very poorly soluble in cold water and thus an unsuitable agent for use in practical disinfection.

Cresols. The three isomeric forms of cresol, ortho-, meta- and para-cresol, form the basis of a large number of proprietary disinfectants. The cresols are only moderately soluble in water, to the extent of about 2 per cent., and are therefore generally emulsified with soap.

Like phenol the cresol compounds are effective against a wide range of bacteria, including the acid fast organisms. Spores are, however, resistant and 2 per cent lysol fails to kill anthrax spores in 92 hours. The viruses, too, are more effectively destroyed by other agents, e g, caustic soda or formalin.

The presence of soap renders solutions of the cresols suitable for cleansing purposes and thus increases their effectiveness; on the other hand excessive quantities of soap reduce their disinfectant powers. Emulsified disinfectants are more powerful than solutions of equal strength, this effect being due to absorption on the bacteria of the small particles of the emulsion leading to a local concentration of the disinfectant in the immediate vicinity of the organisms. The cresol disinfectants are comparatively cheap, of reasonably low toxicity and, like phenol, maintain much of their effectiveness in the presence of moderate amounts of organic matter. It is important that they be used at the correct strength and, since their powers are enhanced at higher temperatures, hot solutions should be employed whenever practicable. In preparing solutions soft water should always be used if possible, since hard water will cause precipitation of the soap.

✓*Liquor Cresolis Saponatus.* B P, contains 50 per cent. by volume of the cresols, the solvent being prepared by the action of an aqueous solution of KOH or NaOH on a vegetable oil, e g, linseed oil. It forms a clear solution in water, with which it mixes in all proportions. In the B P it is stated that—"the term 'lysol,' as a synonym for a Solution of Cresol with Soap, is limited to Great Britain and Northern Ireland," Elsewhere, however, the term lysol is a trade-mark and the name is restricted to the preparation issued by the owner of the trademark. The commercial preparations of lysol contain about 50 per cent of the mono-methyl phenols, with an admixture, in some cases, of smaller quantities of the still higher homologues, e g, xylenol.

Lysol is about three times as powerful a disinfectant as phenol but different preparations vary considerably in their germicidal action. It is generally used for disinfectant purposes in a concentration of 2 to 3 per cent.

✓*Proprietary coal-tar disinfectants,* of which there are many well known examples on the market, contain the higher homologues of cresol together with soaps and oils and form milky emulsions in water. They are of low toxicity and the better products are reliable disinfectants with a wide range of anti bacterial activity. The strength in which these disinfectants are generally used varies from 1 to 3 per cent.

Formaldehyde, Formalin. Formalin is an aqueous solution of formaldehyde gas containing not less than 37g. of Formaldehyde in 100 ml. Although it is a powerful bactericidal agent there is a considerable lag period before formalin begins to exert its effect. This period is reduced at higher temperatures and the overall efficiency of formalin as a disinfectant increases when the temperature is raised. Warm solutions are thus to be preferred for practical disinfection purposes.

The power of formaldehyde as disinfectant is not markedly reduced in the presence of organic matter and it is an effective agent against a wide range of bacteria and their spores. A 5% solution of commercial formalin was found by Topley and Wilson to kill anthrax spores in ninety minutes and this solution is also useful in dealing with tuberculous sputum and similar material. Though formalin has some virucidal ability it is not, owing to the lag period, so effective in this respect of some other agents, *e.g.*, caustic soda.

Formalin makes leather brittle, it should not therefore be used on harness. Its use in disinfecting imported wool and hair is referred to on page 370, and the use of formaldehyde gas as a fumigant is dealt with on page 317.

Benzene Hexachloride. The gamma isomer of benzene hexachloride is a most useful agent for the destruction of ectoparasites on animals and is extensively used as a dressing in many parasitic skin diseases. It is also a very valuable product for the disinfection of stalls, loose-boxes, kennels or poultry houses which have housed animals affected with mange acari, lice or fleas.

A solution containing at least 0.1 per cent. of the gamma isomer should be used as a disinfectant in such cases, applied as a spray. Alternatively benzene hexachloride 0.1 per cent. in dust form may be applied to such places as the perches in poultry houses after a thorough cleansing of the premises, or special "candles" containing benzene hexachloride may be employed ; these, on ignition in the loose-box or other building, distribute a thin film of benzene hexachloride over all exposed parts of the premises.

STANDARDISATION OF DISINFECTANTS

Whilst it is very desirable that there should be some method of measuring the relative bactericidal powers of disinfectant no completely satisfactory method is available.

In the *Rideal-Walker* method varying concentrations of the germicide and of phenol are allowed to act on the test organism (usually *B.*

t)phosus), a minimal amount of organic matter being present. Subcultures are made at intervals of 2¼ minutes into tubes of nutrient broth, and the absence or occurrence of growth after 7 days' incubation is taken as evidence of the destruction or survival of the organisms in the disinfectant mixtures. The weakest dilution of phenol which sterilizes the suspension in a given time is divided by the weakest dilution of the disinfectant that is lethal in the same time. For example, if the test organism is destroyed in 10 minutes by a 1-100 concentration of phenol, whereas it is killed in the same time by a 1-1000 dilution of the disinfectant under test, the phenol coefficient of the disinfectant would be 10.

In the *Chick Martin Test* the disinfectant is allowed to act on a test organism (B typhosus) for a fixed time viz. 30 minutes, at a definite temperature, 20 C (68 F) in the presence of a considerable amount of organic matter as represented by a 3 per cent suspension of dried human faeces. Its germicidal action under these conditions is then compared with that of phenol.

Both the above tests have the disadvantage that they only assess the value of a disinfectant against one particular organism under one particular set of conditions and are also of little value in assessing disinfectants which are unrelated to phenol and which exert their action in an entirely different way.

"APPROVED" DISINFECTANTS

When disinfection is to be carried out after an outbreak of any of the diseases which are notifiable under the Diseases of Animals Acts the disinfectant used must be one which is approved for the purpose by the Minister of Agriculture and Fisheries and it must be used at a specified dilution.

The Diseases of Animals (Disinfection) Order, 1936, specifies that the disinfectant used in such circumstances must be either at 5% standard phenol solution or an approved disinfectant used at a specified dilution. An approved disinfectant must be labelled as such and the dilution at which it is to be used must be indicated on the container.

GASEOUS DISINFECTION (FUMIGATION)

Gaseous disinfection was at one time practised to a very great extent, and much dependence was placed upon the supposed power of the generated gases to destroy pathogenic organisms. It is now

known that the utility of gaseous disinfection is very limited, and that the "disinfection," even under the most favourable circumstances, is mostly unsatisfactory.

Fumigation has, as its object, penetration of the gas into all parts of the room or building, so that the surfaces of the floor, walls etc., may be disinfected. Insects, rats and other vermin are also destroyed by this means. To be effective, the chamber must be rendered air-tight, otherwise constant dilution of the fumigant takes place through diffusion of air into the apartment, with simultaneous escape of the disinfectant gas. Even in the case of a room in an ordinary dwelling-house, when elaborate precautions are taken to make the chamber gas-tight by covering the fire-place aperture and sealing the window, door and key-hole with adhesive paper, a certain amount of dilution takes place. In stables, byres, etc., where it is an impossibility to prevent the ingress of air, gaseous disinfection should not be attempted but it may possibly be used in dog-kennels and catteries and in suitably constructed loose-boxes. Fumigation of incubators is a useful measure for the control of salmonella infections in poultry (see page 438).

Fumigation of ships is extensively practised, chiefly for the lethal effect of the gas on vermin which might be disease carriers.

Sulphur Dioxide. Fumigation with sulphur dioxide is of little value for disinfectant purposes in veterinary hygiene. Against rats and other vermin this gas is more effective than formaldehyde, but is itself inferior to hydrogen cyanide in this respect.

The gas may be generated by burning rock sulphur, the ignition being aided by methylated spirit and wood shavings, or by burning specially prepared sulphur blocks or candles in which sulphur is combined with combustible substances. In either case a water bath should surround the ignited material as a great deal of heat is evolved. The quantity of sulphur required is 6 to 8 lbs. per 1,000 cubic feet of space and the gas should be allowed to act for at least eight hours. Alternatively sulphur dioxide in cylinders may be used whilst a number of proprietary fumigants employ sulphur as a base.

Sulphur dioxide is more than twice as dense as air, and does not therefore diffuse well. Though it is the usual custom to ignite the sulphur at floor level, better results are possibly obtained when the holder containing the sulphur is suspended near the ceiling or roof.

Metal surfaces are tarnished by the gas and the colour of fabrics is bleached. Food stuffs, such as hay, oats, etc., very readily take on the disagreeable odour of burning sulphur.

Formaldehyde Gas. Formaldehyde gas is a more efficient bactericidal agent than SO_2, but is less destructive to insects and rodents.

Its action is favoured by a room temperature of about 70°F. and a relative humidity of 70 to 75. Formaldehyde may be obtained from a solution of formalin by evaporation under certain conditions, or by treating the solution with various chemicals. If an attempt is made to volatilise formaldehyde by heating a concentrated formalin solution in an open vessel, it is found that water vapour is generated more rapidly than formaldehyde, and the concentration of formaldehyde in the solution increases. As soon as the concentration of the aldehyde in the water exceeds 40 per cent. polymerisation occurs and the inert compound paraformaldehyde is formed. This method is therefore unsatisfactory as a means of generating the gas. Polymerisation of the formaldehyde in solution may be prevented in many ways, e.g. by adding 10 per cent. of glycerine to the formalin or by diluting the solution so that the proportion of formaldehyde present does not exceed 8 per cent. When a solution of the latter strength is evaporated water vapour and formaldehyde are generated at approximately equal rates.

The method most frequently used for the generation of formaldehyde gas is the interaction of formalin and potassium permanganate. This method is approved by the Ministry of Agriculture and Fisheries for the fumigation of fodder on premises where there has been an outbreak of foot-and-mouth disease. For the disinfection of each 1000 cubic feet of the total space occupied by the air and fodder in the room 1 lb. of potassium permanganate and 1 pint of formalin are used.

The permanganate is placed in a bucket or other large open vessel on the floor, or the bucket may be placed in another receptacle which will catch any overflow of liquid when the gas is liberated. The correct amount of formalin is poured quickly on to the permanganate crystals and the operator withdraws rapidly closing the door as tightly as possible. Twelve hours should elapse before the gas is allowed to escape. To get rid of the irritating vapour after disinfection is completed the room should be thoroughly ventilated and a dilute solution of ammonia may be sprinkled on the floor. The method for use in egg incubators is described on page 438.

Exposure to formaldehyde vapour is also approved as a method of disinfecting straw, hay or chaff that is imported as packing, etc., into Australia, Canada and New Zealand. Under the regulations of the Quarantine Act, 1908-1924, of the Commonwealth of Australia, a certificate has to be given that "Straw used in the manufacture of the articles or in the packing of the goods in the shipment . . . has been placed loosely in a compartment having a temperature of not less than 65°F.; and thoroughly sprayed with 10 fluid ounces of formaldehyde solution (containing not less than 37 per centum of formaldehyde by weight) for each 1000 cubic feet of space in the compartment, the com-

partment being immediately closed in such a manner as to prevent the escape of the formaldehyde vapour, and being kept closed for not less than eight hours." Disinfection by steam is an alternative method (page 306).

Hydrogen Cyanide. (Prussic Acid, HCN). Hydrogen cyanide is a liquid which boils at 79° F., and is therefore a gas at a temperature little warmer than that of an ordinary room. The gas is colourless and has the odour of bitter almonds. It has no value as a bactericide but is used for the fumigation of ships in order to free them of rats and insect pests and for the destruction of insect pests in human dwellings.

On account of the danger to human life, fumigation by HCN must be carried out by a specially trained staff.

Prior to the fumigation of a ship by hydrocyanic acid gas the most rigorous measures must be taken to ensure that no person is left abroad with the exception of the officer in charge, the watchman and the operators. The quayside should also be controlled, and no ship with persons on board be permitted to lie alongside. Port-holes, ventilators, and holds are closed, the hold hatches being covered with tarpaulins, and the portion of the ship to be fumigated is made as gastight as possible. Within that space, passage doors, etc., are opened so as to permit the free access of the gas to all parts. Cupboards, drawers, etc., should be left open, so that the gas may enter and destroy insects. The bilges, pipe casing and other inaccessible parts where rats are likely to lurk should be opened up to facilitate penetration of the gas. The lifeboats must also be prepared for fumigation. Food and fluids used for drinking should be removed. The ship should also be examined for places where the gas is likely to collect in "pockets," so that special attention may be given to the ventilation of these areas after fumigation.

The gas may be generated in several ways, as, for example, by the action of an acid on sodium cyanide. For each 1000 cubic feet of space 5 ounces of sodium cyanide are treated with a mixture of 7½ ounces of commercial sulphuric acid and 10 ounces of water. The specific gravity of the gas is approximately the same as that of air and its rate of diffusion is consequently slow. In a ship where there are passages and a number of holds and other spaces hydrocyanic acid gas should therefore be evolved at several points. It has been suggested[*] that the diffusion of HCN may be hastened by liberating the gas in the upper decks and withdrawing air from the bottom of the ship through the sounding pipes. The fumigant spreads downwards and is distributed more rapidly throughout the ship.

* Park, Ross and Larmuth, *Journ. Roy. San. Inst.*, 1933, Vol. LIV., p. 35.

Alternatively hydrocyanic acid gas may be generated by the use of Zyklon or from liquid hydrogen cyanide

Zyklon is a proprietary substance consisting of kieselguhr impregnated with a mixture of liquid HCN (95 per cent) and of chloropicrin (5 per cent), the tear gas warns persons if there is a dangerous amount of HCN in the air   Zyklon is stored in strong hermetically sealed tins containing various amounts of HCN, e g , 500, 1000 and 1500 grammes   The tins are opened with a special tool which prevents the escape of gas, and quantities of Zyklon are scattered in thin layers on sheets of paper or canvas placed at suitable positions in the ship   The two chemical fluids contained in the porous diatomaceous material then, volatilise and diffuse into the surrounding air. Two ounces of the net HCN content are allowed for each 1000 cubic feet of space and an exposure of 2 hours is given   At the end of this time the ship is opened up and thoroughly ventilated   After time has been allowed for the gas to dissipate a cage containing a rat or canary may be lowered into the hold: if the animal is unaffected by exposure for at least 10 minutes operators with gas masks enter the ship and remove the residue of the Zyklon   The ship may be considered safe for occupation when all parts, including the suspicious areas where gass is liable to "pocket," can be entered without discomfort from lachrymatory gas

The gas may also be obtained by the vaporisation of liquid hydrogen cyanide, which is contained either in strong glass bottles or in steel cylinders   Two ounces of fluid are allowed for each 1000 cubic feet   For the fumigation of a loaded ship the quantity of HCN should be doubled, and, in addition, it may be necessary in some ships to give an exposure of 4 hours   Liquid HCN is also procurable in vessels containing a warning lachrymatory gas

DISINFECTION OF ANIMAL HABITATIONS

It has already been stressed that the power of all disinfectants is reduced in greater or lesser degree by the presence of organic matter which exerts a protective action on bacteria and, in some cases, has a direct neutralizing effect upon the disinfectant   The first essential, then, in practical disinfection will be the removal of as much organic material as possible and a thorough cleansing with a suitable detergent of the area to be disinfected   Secondly, a disinfectant which is of proved value against the organisms concerned must be used and it must be applied in such a way to ensure the most through contact with the bacteria

The methods to be adopted in disinfection of premises after an outbreak of disease will depend upon our knowledge of the organism

concerned ; its virulence, method of spread, whether or not it is able to form resistant spores and other factors must all be taken into account. Whilst they will have to be modified in particular cases certain basic rules can be laid down :—

1. Prevent access of unauthorised persons and animals to the premises.

2. Remove all dung and litter, scraping dry material from the floor and walls. This should be disposed of by burning, or if this is not possible it should be stacked separately and subsequently distributed on arable land to which animals have no access. In cases of anthrax and glanders, the whole of this material and the surrounding area should be soaked in an approved disinfectant before any attempt is made to remove it.

3. The walls (to a height of at least 6 ft.), floor, troughs and fittings should be thoroughly cleansed by scrubbing with a hot 4 per cent. solution of washing soda (approximately a double-handful in three gallons of water). If the floor is of earth the top four inches of surface soil should be removed and disposed of in a similar manner to the litter.

4. Now thoroughly coat the whole area with an approved disinfectant. This is best applied by means of a spray with as much pressure as possible.

5. Leave the disinfectant to act for twenty-four hours.

6. After twenty-four hours, wash out the building with clean cold water and then leave it, with all windows and doors open, to dry.

At the conclusion of the process of disinfection all the tools used in the operation, shovels, forks, buckets, barrows, etc., must themselves be thoroughly cleansed and disinfected. The attendants carrying out the disinfection should wear rubber boots and protective clothing which can be disinfected after use. In cases of anthrax, rubber gloves should be provided and due emphasis placed upon the importance of avoiding any personal contact with blood from the carcase.

The procedure to be adopted in disinfecting after an outbreak of any of the notifiable diseases is dealt with in the section devoted to those diseases (pp. 365f.) and mention is also made of other, non-notifiable conditions in the control of which disinfection and general hygiene play a considerable part (pp. 423f.).

The method of disinfecting transport vehicles, in accordance with the Transit of Animals Orders is described on page 446 and the disinfection of incubators is considered on page 438.

Disinfection of Cattle Yards. When disease has occurred in a cattle yard all litter and dung to a depth of about eighteen inches should be removed and stacked separately from other manure. It should be left

thus for some time to allow the generated heat to destroy pathogenic organisms and then should be distributed on arable land When there is not much litter the top four inches of soil should be removed, mixed thoroughly with quicklime and disposed of in such a way that animals will not come into contact with it If there is a carcase to be buried this top soil should be buried at the same time

Disinfection of Pastures   It is not possible to carry out any large scale disinfection of pasture-land after an outbreak of contagious disease but certain practical steps can be taken to hasten the destruction of harmful micro-organisms by natural processes

All susceptible animals should be denied access to the infected pasture Any obvious infective material, e.g., an aborted foetus, should be removed and destroyed by burning or by burial six feet deep with quicklime The turf which has been in contact with infective material should be dug up and disposed of similarly

When the system of farming permits, the land should be ploughed up, but in any case it should be kept free of susceptible animals for as long as possible Where it is impracticable to use the plough the chain harrow may be employed to break up pats of dung and thus hasten the destruction of micro organisms by the desiccating effect of the wind and the sun

The use of quicklime, which is sometimes recommended for the destruction of pathogenic organisms on the land, is of questionable value If it is so used it is applied in the proportion of at least two tons to the acre

DISPOSAL OF CARCASES

It will be realised that the proper disposal of the carcases of animals affected with contagious diseases, and in particular "notifiable" diseases, is of the utmost importance in order to prevent the spread of disease and as in the case of anthrax, to prevent human infection The Ministry of Agriculture and Fisheries under the Diseases of Animals Act, 1950, have authority to make such Orders as they may think necessary for "prescribing and regulating the destruction, burial, disposal or treatment of carcases of animals dying while diseased or suspected" and for "prohibiting or regulating the digging up of carcases that have been buried"

Various Acts and Orders specify the manner in which carcases of animals suspected to have died of notifiable diseases are to be disposed of Section 6 of the Dogs Act, 1906, makes it an offence for any person

to permit the carcase of any head of "cattle" to remain unburied in a field to which dogs can gain access. "Cattle" for this purpose includes horses, asses, mules, sheep, goats and swine. When an "animal" has been buried it is illegal to dig it up again; permission to do so must be obtained from the Ministry of Agriculture and Fisheries. It should be clearly understood that this prohibition does not refer solely to carcases of animals that were affected with notifiable diseases. The law, which is clearly stated in several Orders, is quite definite. For example, Article 16 of the Animals (Miscellaneous Provisions) Order of 1927, states :—"It shall not be lawful for any person except under and in accordance with the provisions of a licence of the Minister or the permission in writing of an Inspector of the Ministry, to dig up, or cause to be dug up, the carcase of any animal that has been buried."

Article 1 of this Order defines Animal as "cattle, sheep, goats, all other ruminating animals, and swine, horses, asses, mules, dogs, and cats."*

For legislative purposes, carcases can be placed in either one of two groups—(a) those of animals which were affected—or suspected to have been affected—with a notifiable disease, and (b) those which were not so affected. In the case of the first group, specific instructions as to the disposal of the carcases are issued with each relevant Order. They have to be buried, cremated, or taken to a destructor. Article 15 of the Animals (Miscellaneous Provisions) Order gives power to a Local Authority to move carcases for the purpose of destruction :—

"Any carcase required by any Order of the Minister to be disposed of by the Local Authority may, notwithstanding anything in the Order prescribing the mode of disposal, be destroyed by the Local Authority by exposure to a high temperature upon the farm or premises upon which the carcase is, or upon the nearest available premises suitable for the purpose, but the carcase shall not be taken into the district of another Local Authority without the previous consent of that local Authority."

Disposal by a local authority at a central destructor of animals affected with contagious diseases is a more sanitary proceeding than burying them on farms and, where circumstances permit, a local authority possessing a destructor should grant facilities for a neighbouring authority to use it.

It is an offence to throw into the sea within the three-mile limit or into any river, stream, canal, navigation or other water the carcase of any animal which has died of disease or has been slaughtered as diseased, or suspected of being diseased (Diseases of Animals Act, 1894, sec. 52).

*Order amended 1938.

Burial. If disposal is by burial, the carcase must be buried in its skin, be covered with a sufficient quantity of quicklime or other disinfectant and have not less than 6 feet of earth above it

In all cases, other than anthrax, the skin has to be so slashed as to render it useless

It may be noted that the "quicklime" used is very often well slaked and therefore has no erosive action on the carcase   Slaked lime and other "disinfectants" may in fact actually retard decomposition of the carcase

The burial place must be distant from a well or water course   In some districts it is impossible to get the necessary depth before coming to water, and also in some localities it is difficult to dig the required depth owing to rock   When a large number of carcases is to be buried a mechanical excavator may be used to dig out the necessary pit   When a post mortem examination has to be made it is wise to have the carcase lying at the edge of the grave, i e, the grave digging should be completed before the carcase is cut   The object of this is to ensure safe disposal of the viscera and carcase with the soiled earth and grass, the fouled top-soil, with a margin for safety, should be lifted and thrown into the pit before it is filled in   As the smell of the carcase may attract foxes and dogs, the area may be watered with a coal tar disinfectant which will act as a deterrent for a sufficient length of time   It is customary to fence off the area with a strand of barbed wire.

Cremation of Carcases   The Ministry of Agriculture recommend the following methods* for the cremation of anthrax carcases, either of which will be found suitable for dealing with individual carcases on farm premises in rural districts —

The Pit Method.   For the carcase of a large cow, dig a pit measuring about 7 ft by 4 ft by 18 in deep   The depth of the pit can be increased if desired, but there is little to be gained by so doing.   A trench about 9 in wide and 9 in deep is next dug right across the bottom of the pit, the ends of this cross trench being extended beyond the pit and sloped upwards so as to reach ground level about 2¼ ft from the edges of the pit   The object of this trench is to provide for draught and to facilitate the lighting of the fire

The fire may be laid in the following sequence —

(1) Lightly fill the trench with straw soaked with paraffin, the straw

being extended along the draught channels to ground surface to provide lighting points.

(2) Place a few pieces of heavy timber, iron rails or other suitable material at intervals across the ventilation trench so as to prevent its obstruction.

(3) Cover bottom of pit with thin pieces of wood, e.g., faggot wood.

(4) Add larger pieces of wood, e.g., cord wood.

(5) Saturate with paraffin.

(6) Add coal.

The pit if constructed about 18 in. deep will now be filled with fuel to about ground level and the carcase can thus easily be placed in position.

The fire is started by lighting the straw at one or both ends of the lighting points.

Surface Burning Method. This method can usefully be adopted when labour is scarce or when the nature of the ground is not suitable for the construction of a pit, i.e., when the land is waterlogged for the subsoil is of rock.

(1) Two parallel trenches about 5 ft. by 9 in. by 9 in. deep and 2 feet apart are dug in the direction of the prevailing wind, at the site selected for cremation.

(2) The carcase is placed over the trenches.

(3) Coal is placed on and around the carcase.

(4) Cord or similar type wood is added to the windward side of the coal.

(5) Faggot or similar type wood is now placed in position on the windward side.

(6) The wood is soaked with paraffin.

(7) A small quantity of paraffin-saturated straw is added.

The fire is then lit.

For the cremation of the carcase of a large cow by the pit method, approximately ½ ton coal, ½ ton wood, a truss of straw, and 2 gallons of paraffin are required. As a general rule it will be found that more fuel is required for surface burning than in the case of the pit method.

When a large number of carcases is to be disposed of by burning some modification of the pit method is usually adopted. It may be done as follows :—

Dig a shallow trench about 3 feet wide and 9 inches deep; the length will depend upon the number of carcases to be cremated, and for this purpose there should be an allowance of 1 yard for each carcase. In the centre of the shallow trench another narrow draught trench, 9 inches deep and 9 inches wide, should be dug out and con-

tinued longitudinally for about a foot at either end, and cross trenches of the same size should be put in at about 6 feet distance apart.

A few stout beams of wood should be laid across the trench, taking care not to fill up the draught trenches. On top of the wood should be placed about one-third of the quantity of coal required and then the
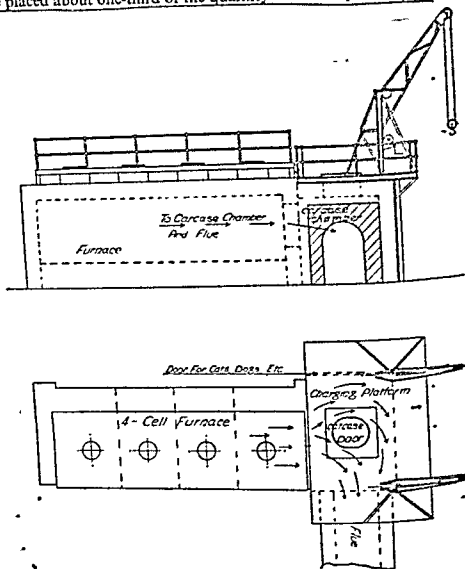
Fig. 105.—The Edinburgh Cleansing Department Incineration Chamber for Animal Carcases. The top figure illustrates the Incineration Furnace showing the inlet of burning gases to Combustion Chamber, also the Charging Platform with Carcase Crane. The lower figure illustrates the furnace showing four cells with charging holes for the reception of combustible refuse and the direction of burning gases into the Combustion Chamber and Flue.

carcases should be drawn across on to the pit and turned on their backs, every alternate carcase having its head on the opposite side of the trench from its neighbour. The remainder of the wood should be

placed around the carcases and the coal on top of it and then the fire is ready to light. To get the fire started a liberal supply of straw and paraffin should be at hand, and then no difficulty will be experienced.

Where pig and sheep carcases are also to be cremated they can be piled into the spaces between the bovine carcases.

The quantity of coal required will depend on the size of the animals, but 5 cwt. for each bullock or cow is ample, and where there are many carcases less coal in proportion will be required. Two to three tons of wood is sufficient for 20 to 30 tons of coal, but it will be readily understood that where there are not many carcases more wood will be required in proportion. In times of fuel shortage, the alternative method of disposal by burial must be adopted.

Flame Gun Method. Recently some experiments have been carried out on the destruction of single carcases by means of "flame guns." In this case no pit or trench is necessary and the carcase is gradually destroyed by directing a powerful flame on to it as it lies on the surface of the ground or on corrugated iron sheets. The time taken depends on the number of flame guns available; it has been shown that the carcase of a cow can be destroyed in five hours using ten guns at a cost of about £2.

Incineration in a Destructor. While the method of cremating an anthrax carcase or a carcase affected with any other notifiable disease which has been described is admirable on isolated farms, Local Authorities should be encouraged to provide destructors to which carcases can be taken in a properly constructed float. The advantages of this are obvious ; trained men handle the carcases with proper precautions ; the carcases are safely disposed of without dragging them across yards and fields, the labour is less, and the surrounding neighbourhood is not disgusted by the smell of burning flesh. In short, incineration in a destructor is expeditious, safe and economical. The most satisfactory method of destruction by this means is probably to be found in the provision which is usually made in connection with incinerators or destructors erected for the disposal of towns' refuse. Where such furnaces exist the grates or furnaces are usually arranged in series and a combustion chamber separates the furnace structure from the flue which conducts the products of combustion to the chimney. The position of this combustion chamber in the track of the combustion gases ensures that the highest temperature will occur at this point and it is usual to provide a door to this chamber for receiving carcases of dogs and cats and other material. Carrying this idea a stage further, the roof of the combustion chamber can be constructed so as to leave an

orifice sufficient to admit the carcase of a bullock, and this opening is fitted with a movable cover of cast iron A simple form of hoisting tackle suffices to remove this cover plate and to lift the carcase and lower it into the combustion chamber The accompanying illustration shows the construction of the facilities provided in Edinburgh at the Powderhall Depot of the Cleansing Department Observations which have been carried out show that the temperature in the combustion chamber under normal conditions reaches 1300°C, and that the carcase of a bullock of average weight is completely disposed of in the space of 2 hours It is very important to see that a good heat is generated *before* the carcase is placed in the chamber

Knackeries Knackeries serve an extremely useful purpose in the agricultural world by gathering up cadavers and animals which have to be killed which would otherwise be a nuisance Further, they convert waste and obnoxious material into useful commodities such as food for cats dogs, and poultry, and meat and bone meal and fertilisers Knackeries are to a certain extent controlled by the Protection of Animals Act, 1911, and the Scottish equivalent Act of 1912 and also by the Food and Drugs Act, 1938 As an offensive trade a knackery comes under the jurisdiction of local authorities

No carcase of a bovine animal which has been found dead without any history of disease should be admitted into a knackery unless accompanied by a veterinary surgeon's certificate stating it to be free from anthrax

DIPS AND DIPPING

Historical. The practice of dipping as we now understand the term is a development of comparatively recent times, dating from the first decade of the nineteenth century Prior to this time, hard-dressing, as distinct from immersion, was the rule, excepting immersion of sheep in river or sea water as a preliminary or adjunct to hand treatment with an antipsoric dressing.

M P Cato, in his *De re Rustica*, written some 200 years B C, describes a mixture of lees of oil and wine, decoction of lupin and water, which was applied by hand to the skin of the sheep after shearing. Two or three days later the sheep were washed in the sea or in sea water This treatment was claimed to be successful for sheep scab, to protect the animals from tick infestation, to increase the yield of wool and to improve its quality Vergil alludes to the practice in his time of smearing scabby sheep with an ointment composed of bitter oil lees, spume of silver, native sulphur, Idean pitch, fat wax, squill,

hellebore and black bitumen, followed by immersion in a stream or river (Fig. 106). Later classical authors merely repeat such information, and the use of these methods continued into the Middle Ages. In the fourteenth and fifteenth centuries the salving of scabby sheep with tar, mixed with oil or grease, or with a mercurial ointment, became the standard treatment. Fitzherbert, in his *Boke of Husbandry*, published in the year 1534, was still recommending the use of "meddled tar," but describes an elaborate dressing, consisting of broom cops, leaves and flowers, chopped small and boiled in water until the preparation thickens to a jelly-like consistence. To this decoction were then added sheep's suet, stale urine and brine. The mixture was then strained through a cloth, and while still lukewarm applied to the skin of the affected sheep with a sponge or a "piece of an old mantle." In the eighteenth century infusions or decoctions of tobacco, with or without additions, appear to have been used to some extent in Germany.

The treatment of sheep scab by immersion of the affected animal in an antipsoric fluid was introduced by the French agriculturist, Tessier, in the year 1810. Tessier's dip consisted of a solution of arsenious acid and sulphate of iron. The solids were boiled in water to effect solution, and the final product contained about 0.82 per cent. of arsenious oxide. The excess of the iron salt was supposed to exert an astringent action on the sheep's skin and to prevent absorption of the toxic agent. Variations on Tessier's formula were brought out from time to time. Bitter substances, such as gentian root and aloes, were often added with the object of rendering the dip unpalatable, thus checking any disposition of the sheep to drink the dip. All of these preparations were crude and dangerous. Deaths from arsenical poisoning were frequent, and iron-staining of the fleece was a serious objection. William Cooper, an English veterinary surgeon, invented the arsenic-sulphur powder dip in 1843, and in the latter half of the nineteenth century the coal-tar creosote and carbolic dips began to be developed.

The discovery by Smith and Kilborne, in 1893, of the association between tick infestation and bovine piroplasmosis led to the first experiments in cattle dipping in the United States of America. It was common experience that any kind of oil or grease would destroy ticks when applied to cattle infested with these parasites, and this led to attempts to apply oil by means of the dipping bath. Crude cotton seed oil and various petroleum oils were tried, the oil being floated in a layer two to three inches in depth on the surface of the water in the dipping bath. Oils were also sprayed directly on to the skins of the cattle. Fairly good results were obtained in the control of ticks, but the cattle were apt to suffer from the adverse effects of these oily

dressings. Ultimately it was found that certain arsenical solutions were highly efficacious against ticks and non-injurious to cattle, and arsenical dips have been extensively used in all the stock-raising countries of the world for the control of tick infestations of cattle.

The discovery of the parasiticidal activity of DDT and benzene hexachloride has provided powerful new weapons in the control of ecto-parasites of sheep and cattle by means of dipping. The fact that dips

FIG. 106 —From an old woodcut illustrating Vergil's observations on sheep scab and its treatment (*Georgics, Lib. III.*).

containing these products exert a considerable residual effect increases their value as compared with other dips, the effect of the latter being, in general, of short duration.

SHEEP DIPS

Arsenic-Sulphur Powder Dips. These dips are usually prepared with arsenious oxide, sulphur and sodium carbonate. The final product consists of a complex mixture of arsenic sulphides, other arsenical compounds and sulphur. To comply with the requirements of the Ministry of Agriculture (Great Britain) arsenical sheep dips, diluted for use, must contain not less than 0.20 per cent. of total arsenic (expressed as arsenious oxide), including not less than 0.13 per cent. of soluble arsenic (expressed as arsenious oxide). For the purposes of a second dipping within a period of not more than fourteen days after a first dipping with an arsenical dip, the Ministry will approve as efficient a dipping bath containing not less than half the quantity of total arsenic and of soluble arsenic as stated above.

Arsenic-sulphur dips are effective for the treatment of sheep scabies, and also control ked, lice, tick and maggot fly infestations. Though their action is slower but more lasting than that of the phenolic and nicotine dips they cannot compare for residual effect with dips containing benzene hexachloride and DDT.

Coal-Tar Creosote or Phenolic Dips. A typical coal-tar creosote dip consists of a homogeneous solution of a neutral soap or soaps in a coal-tar creosote. The composition of the coal-tar creosote varies according to its origin, whether from horizontal or vertical retort gas tars, from blast furnace tars, or from low-temperature distillation tars, but, in general, may be taken as a mixture of coal-tar acids (phenols), neutral hydrocarbon oils and, to a minor extent, pyridine bases. The crude product usually contains an excessive amount of naphthalene, which has to be removed by chilling and filtration before the creosote is suitable for the manufacture of a satisfactory sheep dip. When diluted with water, the homogeneous solution forms an emulsion which should show no tendency to separate. The stability of the emulsion depends upon the presence of the soap, and as most natural waters contain lime and other mineral salts which combine with the soap and thereby render it inert, it is desirable that a coal-tar creosote dip should contain sufficient soap to allow of the use of moderately hard waters for its dilution. Sometimes these dips are made in paste form instead of liquid, but they possess little advantage in this form and are more difficult to mix.

The coal-tar creosote dips are quick in action, but are not satisfactory for the treatment of lice and tick infestation, nor do they afford protection against maggot fly.

The standard approved by the Ministry of Agriculture (Great Britain) for tar dips is that the liquid when diluted for use shall contain not less than 0.76 per cent. of total tar oils, including not less than 0.36 per cent. of tar acids.

Nicotine and Tobacco Dips. These dips consist respectively of aqueous solutions of nicotine sulphate or an infusion of tobacco leaf or waste tobacco. The use of nicotine sulphate in the preparation of a dip has the advantage of yielding a product of standard concentration, whereas the nicotine content of a tobacco infusion varies according to the particular sample of tobacco used in its preparation. Concentrated extracts, such as the well-known "Blackleaf 40," are on the market, and are standardised to a definite nicotine content. Nicotine and tobacco dips are effective against all the common ecto-parasites of the sheep, but are expensive, and the extract dips are apt to stain the fleece.

To comply with the requirements of the Ministry of Agriculture (Great Britain), nicotine dips must contain not less than 0 1 per cent of nicotine, and tobacco dips must consist of a water extract obtained by soaking not less than 35 lbs of tobacco in 100 gallons of water

Polysulphide Dips. These include the well-known lime and sulphur dip and the sodium polysulphide dip Lime and sulphur dip is prepared by boiling sulphur and slaked lime in suitable proportions in a definite volume of water After boiling for 30 to 40 minutes, the mixture is allowed to settle The supernatent clear liquid is then run off, and, after dilution, is ready for the dipping bath As the lime used for the preparation of the dip is variable in composition and sometimes of very poor quality, home made lime and sulphur dips are apt to be far from satisfactory, both from the point of view of efficiency and from their injurious effect on the wool Concentrated lime and sulphur solutions are obtainable commercially, and these save the trouble and uncertainty that attaches to the home made product Various formulae for the preparation of lime and sulphur dips are given in the publications of the various departments of agriculture

The formula approved by the Ministry of Agriculture (Great Britain) is that not less than 18 lbs of sulphur with 9 lbs of lime shall be used with each 100 gallons of water

The sodium polysulphide dips are prepared in a similar manner, with the difference that caustic soda is used instead of lime

The polysulphide dips are effective in the treatment of sheep scabies, but are practically useless for all other ecto parasitic infestations of the sheep

Cresylic Acid Dips. These dips contain cresylic acid and soap only, and are readily distinguished from the coal tar creosote dips in the fact that they form a clear or only slightly opalescent solution when diluted with a soft water They are less apt to stain the fleece, and are therefore preferred when it is desirable to retain the whiteness of the fleece after dipping.

Derris Dips. Derris is an effective but slow-killing insecticide with some residual effect Dips containing the active principle rotenone in a bath concentration of 0 01 to 0 02 per cent have been used effectively against keds and ticks

Benzene Hexachloride Dips. The work of recent years has shown that properly formulated dips of benzene hexachloride are capable not only of killing the external parasites of sheep but also remain effective in

the sheep's fleece for much longer periods than other dips. Downing[*] has demonstrated the value of benzene hexachloride dips in the control of psoroptic scab on sheep, a single dipping affording protection for eight to twelve weeks.

The Ministry of Agriculture has now approved certain dips containing benzene hexachloride for use under the Sheep Scab Orders and when these are used a single dipping is all that is required (Sheep Scab (Amendment) Order of 1948). With all other approved dips, double-dipping is necessary (see page 400).

It has not yet been possible to lay down any definite standard for the BHC content of these dips (only the gamma isomer is effective as a parasiticide) and dips submitted for approval are tested individually at the Ministry's Veterinary Laboratory.

Benzene hexachloride dips have also been shown to be very effective against keds, ticks and lice.

DDT Dips. Dips containing 0.5 per cent. DDT have been claimed to give good results in the control of blow-fly strikes in sheep with protection for six weeks or more.[†‡] On the other hand, some workers have found that DDT dips do not give efficient protection to dirty scouring sheep.[§]

Approved composite dips containing DDT and benzene hexachloride are available for use at the summer statutory scab dippings which are usually carried out, in accordance with local regulations, in the months of July or August. Since this period coincides with the time of maximum maggot fly attack the statutory dipping for scab also serves as a preventive dipping against maggot fly.

CATTLE DIPS

From the beginning of the twentieth century cattle dipping as a regular practice has been carried out in all of the stock-raising countries of the world in the warmer latitudes (the Southern United States, Argentina, South Africa, Australia, etc.) almost entirely for the purpose of tick eradication.

In the early days of cattle dipping, soon after the discovery by Smith and Kilborne of the association between tick infestation and bovine piroplasmosis, those dips that had been proved effective for sheep dipping were tried, but it was found that the ticks were highly

*Downing, W. (1947). *Vet. Record* 59, 581.
†Cragg, J. B. (1947). *Vet. J.*, 103, 117.
‡Hughes, L. E., Pollard, E., Field, H. I., and Jones, J. M. (1947). *Vet. J.*, 103, 265.
§Stamp, J. T., Watt, J. A., Beattie, I.S., *Vet. Rec.* 60, 335.

resistant to the treatment, and that remedies which were successful in the control of ked, lice and scab infections of sheep were practically useless for the destruction of cattle ticks when used at strengths compatible with safety to the cattle   Then followed a period in which oily preparations (crude cotton seed oil, light and heavy petroleum oils, oil with sulphur, etc) were used with more or less success, but were generally found to be expensive, severe in their effect on the cattle and, moreover, they left the skin and hair of the dipped animal in a greasy condition that was very objectionable, particularly where dairy cattle were concerned

Attention was then turned to arsenical solutions, and these became a subject for extensive investigation in the United States of America, South Africa and Queensland, Australia   These investigations established the fact that arsenical dips afforded a practicable means of tick control, and they have been extensively used for this purpose   Certain strains of Blue ticks and Cattle Fever ticks are able to tolerate arsenic but these are effectively controlled by dips containing benzene hexachloride   On grounds of economy, however, arsenical solutions are still prepared for most routine cattle dipping, benzene hexachloride being used in areas where arsenic resistant ticks have appeared

The first arsenical cattle dips were prepared by dissolving arsenious oxide (white arsenic) in a hot solution of sodium carbonate   The solution of sodium arsenite thus formed was allowed to cool, and then a small proportion of pine tar was incorporated   Originally, soap was also included in the formula to facilitate the emulsification of the pine tar, but was later found to be unnecessary, and was eventually omitted   A formula prescribed by the U S Bureau of Animal Industry[*] was as follows —

Arsenious oxide (white arsenic)	8 lbs
Sodium carbonate (cryst)	24 lbs
Pine tar	1 gallon
Water to	500 gallons

The arsenic and soda were dissolved in 25 to 30 gallons of water with the aid of heat   The fire was then drawn, and after allowing the solution to cool to 140° F the pine tar was added and thoroughly stirred in   The total bulk was then made up to 500 gallons with water, and the dip was ready for use

An arsenical dip so prepared is not homogeneous, the tar constituents tending to separate out from the concentrated dip on standing.

[*]Ransom B H, and Graybill, H W (1912)   Investigations relative to Arsenical Dips as Remedies for Cattle Ticks   U S Dept of Agriculture, Bureau of Animal Industry   Bulletin 144 65, pp

For this reason it is desirable that the dip should be diluted for use as soon as possible.

Reputable proprietary cattle dips are so prepared as to remain homogeneous in the undiluted condition, and wetting agents are often incorporated to enhance the tick-killing activity.

FIELD TESTING OF DIPS

One of the greatest obstacles to the successful use of dips lies in the uncertainty that may exist with respect to the composition of the contents of the dipping bath.

In many cases the range or dilution of the dip, which is compatible with efficiency as a parasiticide and not injurious to the host, lies within comparatively narrow limits.

Several causes may lead to the use of a dipping bath of the wrong strength. Impure materials may be purchased. Mistakes in the measurements of the dipping bath or errors in the computations are often made by the careless, and sometimes even by the careful, man. All of these sources of error can be checked and guarded against.

The greatest difficulties lie in the maintenance of the bath at the correct strength once it has been prepared.

In the case of sheep dipping, provided that care is taken in gauging the dipping bath and in measuring out the correct quantities of the dip and water, no necessity for field testing will, as a general rule, arise.

In cattle dipping, on the other hand, it is quite another matter. A fresh bath cannot be made up every time a few cattle are to be dipped. Practical considerations make it necessary to use the bath over and over again, often for a period of several months, making up the bath at intervals to replace the dip carried out by the dipped cattle. During this period of time evaporation of the contents of the bath, especially under the hot sun of the South African or Queensland summer, tends to concentrate the dip. This loss may be compensated by marking the level of the wash at the conclusion of each dipping and adding the requisite quantity of water to bring the bath contents to the same level at the next dipping. It is however, difficult to construct large cattle dipping baths which are absolutely watertight, and it is sometimes a matter of uncertainty how much of the loss may be due to evaporation and how much to leakage. Again, rain water, surface water and ground water may enter the bath and dilute the dip by an unknown amount.

It is therefore imperative that some simple field test should be

available to those in charge of cattle-dipping baths to enable them to control the arsenical strength of the dip. The standard method is based on the well-known reversible reaction :—

$$As_2O_3 + 2I_2 + 2H_2O \rightleftharpoons As_2O_5 + 4HI,$$
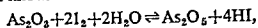
the reaction proceeding from left to right in neutral and alkaline solutions, and from right to left in solutions which are freely acidified with strong mineral acids.

The first reaction is the basis of the simple method for the determination of the actual amount of arsenious oxide in the dipping bath. A solution of iodine of any standard strength is run into any measured aliquot of arsenious solution rendered potentially alkaline with sodium bicarbonate, using starch as an indicator.
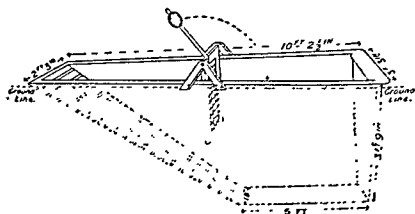
Fig. 107.—Small swim bath, constructed of galvanised iron. Capacity 240 gallons. Suitable for the dipping of small flocks.

When a bath remains filled for a long time oxidation of the arsenite to arsenate may take place and this change cannot be detected by a field test. It is thus desirable in such cases that the bath be emptied and refilled with fresh dip or that a sample of its contents be submitted for laboratory examination before use. If the amount of oxidation is only slight it can be corrected by the addition of a small quantity of horse dung, the bacteria present therein bringing about reduction.

SHEEP DIPPING BATHS

The provision of adequate dipping appliances is a very important contributing factor to the success of the operation, as any result short of complete success means a loss, which, repeated, may exceed the cost of dipping many times over. The fault may lie with the dipping preparation itself, but if a dip with an established reputation be

selected, non-success is generally due to defective appliances and faulty methods.

It should be the aim of every sheep-owner to possess his own dipping bath. The co-operative dipping bath has been tried out in many countries, but, generally speaking, has proved to be unsatisfactory. Sheep-owners who have installed a dipping bath on their own property are better able to select weather conditions suitable for dipping, and they are able to avoid the driving of sheep over long distances, which is one of the most serious drawbacks to the public or co-operative dipping bath.

When considering the construction of a dipping bath, the sheep-owner must be guided by the size of the flock to be dipped and by local conditions. If sand and gravel are easily obtained, a dipping bath constructed of concrete is the cheapest to build and the most lasting. In a district where a suitable building stone is readily available, it is often expedient to build the bath of rough dressed stone blocks set in cement mortar. Where the soil is subject to movement, or under the conditions presented by the deep black soils of Australia, for example, which are so affected by climatic conditions as to swell in wet weather and develop wide cracks in dry periods, a concrete bath is liable to crack, unless expensive reinforcement has been employed in its construction. In firm soils, very satisfactory baths may be built of bricks set in cement, and in districts where suitable timber is at hand, this material may be used for construction. Timber-built baths built to a sound design, and not subject to intermittent drying out, will last for many years. For the smaller sizes of dipping baths, the galvanised iron type is convenient and economical.

The simplest form of dipping bath is the wooden hand bath with a capacity of about 60 gallons. The bath stands on the ground, and a cover is usually fitted, which is folded back when the bath is in operation, and supported by a trestle which serves as a drainer on which the sheep is laid for a short time after its immersion. The sheep are lifted singly into the bath with their backs down and held by the legs by two operators standing one on either side of the bath. A third operator is generally required to take charge of the head of the animal. The operation is very laborious and uncomfortable for the men, and the process is quite unpracticable for the dipping of more than a small number of sheep.

The swim bath is sunk in the ground, preferably with its rim sufficiently raised above the surface to prevent the access of soil and litter. In the smaller types, the sheep are lifted in by hand and leave the bath at the opposite end by an exit slope leading to the draining floor. Small swim baths measure from 7 to 10 feet in length, with

a width of 2½ to 3½ feet at the top, but narrower at the bottom, and a depth of 3½ to 4½ feet (Figs 107 and 108) The wall of the bath at the entrance end is vertical, but the exit end is sloped at an angle of
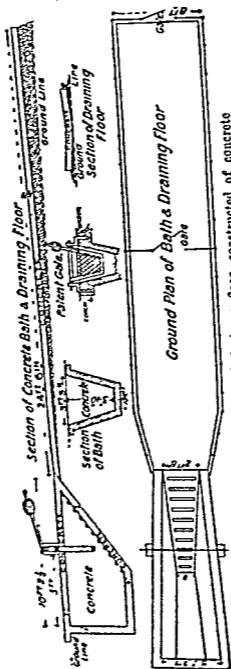
Fig 108 —Small swim bath and draining floor, constructed of concrete

30° or a little more to the horizontal, and furnished with transverse wooden battens or projecting iron strips to give the sheep a secure foothold when leaving the bath. A counterpoised swing gate is usually fitted towards the exit end of the bath to prevent a premature escape of sheep from the bath. A not uncommon practice is to sink a

pit on either side of the bath for the dippers to stand in for convenience in handling the sheep. This is quite unnecessary, and it is much better
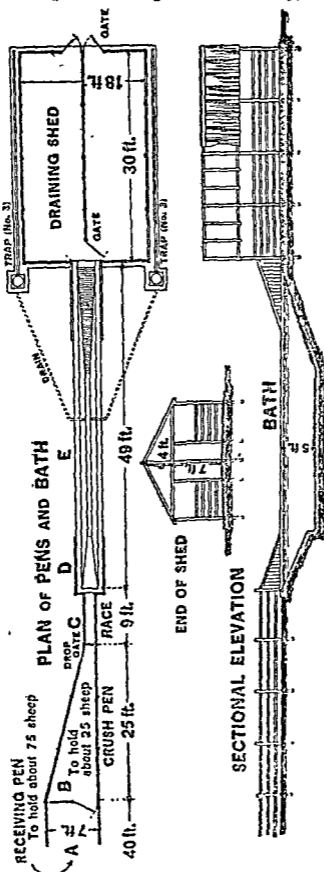
Fig. 109.—Long swim bath, with "walk in" entrance and draining shed

to handle the sheep in the bath from the ground level by the aid of a crutch with a handle of 6 feet or more in length. Short swim baths

are suitable for the dipping of flocks up to 500 head of sheep, but for larger flocks a long swim bath is to be preferred.

Long swim baths (Fig 109) measure from 40 to 80 feet in length, with capacities ranging from 1000 to 4000 gallons, and the sheep enter from a crush race of their own accord, or with a little persuasion from the dipper. One operator stands at the entrance to check a too rapid entry of successive sheep, and one or two men stand at intervals along the side of the bath to immerse the heads of the sheep with the crutch as they swim through and to assist them up the exit slope to the draining floor. The end wall at the entrance end is often made vertical, in which case the sheep plunge directly into the wash.

Fig. 110.—Circular swim bath with central "island." The top of the swing gate, leading to the exit slope, is seen to the left.

If, on the other hand, the floor of the bath is sloped at the entrance as well as the exit end, the sheep are able to walk down into the wash, and, their entry being more gradual, they are not so liable to swallow or aspirate the liquid into the lungs, an accident which may happen when the sheep plunge headlong into the bath.

A type of dipping bath which is widely used in South Africa is the circular swim bath, with or without a central island. Such baths, constructed of concrete, stone or brick, measure from 7 to 9 feet in diameter, with a depth of from 4 to 5½ feet and a capacity of from 500 to 1500 gallons (Figs. 110 and 111). The shape of the bath is that of an inverted truncated hollow cone. From one side of the bath an exit slope, the entrance to which is provided with a sliding or a swing gate, leads to the draining floor. The sheep enter the bath from a crush race or are put in by hand. They then swim round and round

the bath until the gate is opened and allows them to walk up the exit slope to the draining floor. The circular bath is less costly to construct than a long swim bath of the same capacity; it is convenient to use, and requires one man only for the manipulation and supervision of
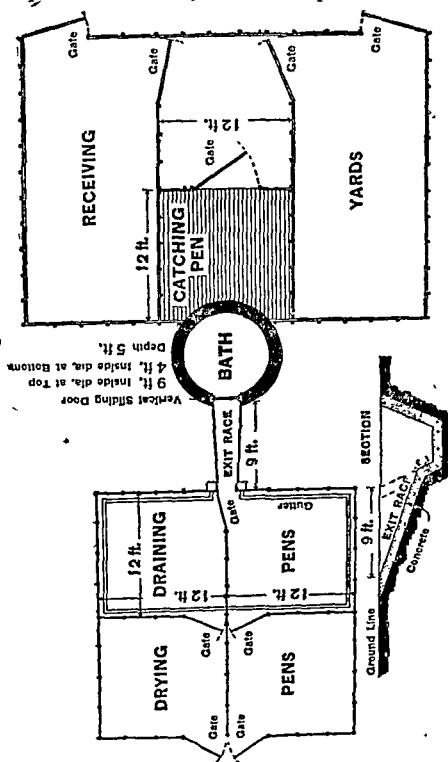
Fig. 111.—Circular swim bath with plan of receiving yards, catching and draining-pens, etc. This type and size of bath is suitable for the dipping of flocks of from 500 to 2000 sheep.

the sheep while in the bath. The building of a central island is not absolutely necessary, but its presence reduces the quantity of dip required to fill the bath to a minimum dipping level, and so reduces the wastage of residual dip. The central island also serves as a platform from which the dipper may conduct his operations.

In the building of concrete dipping baths it is customary to allow an extra 6½ inches all round in making the preliminary excavation to allow 6 inches for the thickness of the walls, bottom and exit and half-an-inch for the cement plaster facing. A timber frame of appropriate shape is then built in the excavation, and the space between the frame and the soil is filled in with the concrete and the bath gradually built up to the coping. Details of construction, quantities, etc., are to be found in various publications of government agricultural departments and others ; "Sheep Dipping Baths" published by Messrs. Cooper, McDougall and Robertson Ltd., Berkhamstead, Herts, England, is a particularly useful booklet.

The exit slope from the dipping bath is an important detail. It is frequently made too steep, and its surface often affords insufficient foot-hold to sheep whose fleeces are laden with liquid and are more or less exhausted at the moment when they are allowed to leave the bath. The inclination of the exit slope should not exceed 30° (1 : 2) by any large amount, and should be fitted with cross battens of wood or strips of tire iron set into the concrete or otherwise fixed to the surface of the slope.

The provision of a draining pen is essential to every dipping bath, and, excepting very small dipping baths, it is desirable that the draining floor area should be divided into two or more pens, with fences and gates so arranged that as one pen is filled it can be closed and an empty pen opened for the reception of the next lot of sheep. The desirable area of the draining floor is decided by the size of the dipping bath and the numbers of sheep that are generally dipped at a time. An allowance of 3 square feet per sheep may be taken as adequate. The draining floor should be impervious to water, and is best made of concrete laid on firm ground. The surface should have a gentle fall of about 1 : 50 to the gutter which conducts the drainings back to the dipping bath, and should be slightly roughened so that dirt and droppings are retained on the floor and can be swept off at intervals, thus preventing excessive contamination of the bath.

In warm countries it is desirable to fix an open roof over the draining pen to afford shelter to the newly-dipped sheep from excessive exposure to sunlight.

To avoid waste of dip arrangements must be made to ensure the return of as much as is possible of the drippings from the draining floor to the bath. When sheep leave the bath, fully half of the wash in a saturated fleece will run off, and if means are not adopted for carrying the drainings back into the bath, all this is wasted. It is therefore customary to construct draining wells with some form of straining device from which the drainings are led back into the dipping

bath. The return pipe from the draining well should be arranged so as to enter the side of the bath as far as possible from the exit end, so as to avoid the accumulation of filth which otherwise would cling to the sheep's backs as they emerge. Many methods of dealing with the drainings have been adopted, but Figs. 112 and 113 will suffice to illustrate the general principle. A second pipe may be led from the draining well to the nearest drain in order to lead off rain water which falls on the draining floor and thus prevent its access into the dipping bath. Where such a device is fitted it is necessary to furnish each pipe with a plug or stop valve, so that either pipe can be closed as the occasion arises.

The sheep dipping bath should always be carefully gauged when it is installed. This can be most conveniently done by running in known

BUCKET WELL
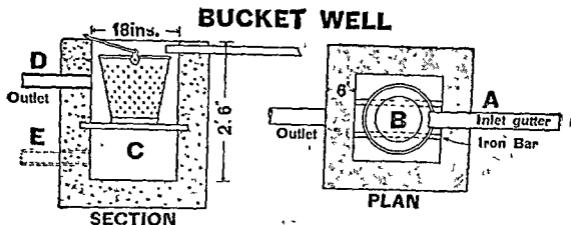
FIG. 112.—Bucket type of Draining Well. A. Inlet gutter carrying drainings from draining pen. B. Perforated bucket to retain droppings and solid matter. C. Trap for fine sediment. D. Outlet pipe returning liquid to the dipping bath. E. If the draining pens are sufficiently high, the outlet may be placed below the bucket, as shown at E. The bucket is supported on two pieces of galvanised iron piping the ends of which are fixed into the concrete sides of the draining well.

volumes of water from a tank of known capacity and noting the level at which the water stands in the bath after each addition. The level should be marked every 20 or 25 gallons. The gauge mark should be affixed permanently to the side of the bath. A rod similarly marked would serve the purpose, but the permanent marking on the walls is preferable. In any event, a marked rod may be kept in reserve, in case the marks on the side of the bath become obliterated.

Much time and labour can be saved by the provision of properly planned receiving, approach pens and entrance crushes. The design of these will vary considerably according to local factors such as the size of the flock, the position of the dipping bath in relation to the approach from the pastures and the type of building materials available.

In some dipping installations a pen to contain two or three decoy sheep is built near the entrance to the bath. The other sheep seeing

the decoys in front of them, are more readily persuaded into the collecting pen

Putting the sheep into the bath by hand is undoubtedly the best
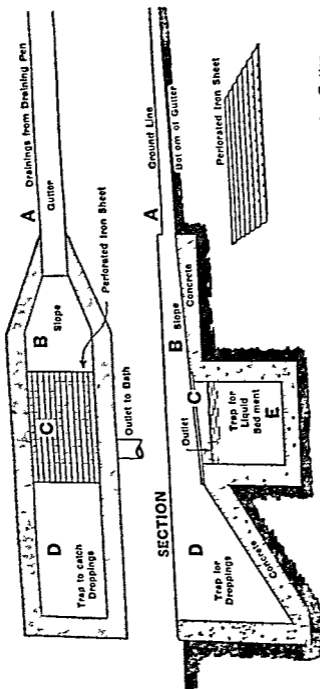
Fig 113—Draining well for reception of dip with returned from the draining floor. A Gutter carrying drainings from draining pen B Slope This allows the liquid to spread and run into the corrugations of C C Perforated sheet of corrugated iron through which the liquid passes to E The droppings and other solid matter remain on the surface and can be easily tipped into the trap D D, Trap with sloping side to facilitate shovelling out E, Trap for sedimentation

method but in very large flocks this may be too laborious and slide-in entries, where the sheep passing in single file along an entrance race find themselves on a slippery slope from which they slide into the bath,

or a tip-platform entry, which allows about six sheep to be discharged into the bath at a time, may be used. Where the latter is employed, however, it must be designed and used with great care if injury to the sheep is to be avoided.

For the construction of the fencing surrounding the collecting and draining pens and forming the sides of the crush and entrance races, it is important that the rails should be fixed on the inside of the posts.

CATTLE DIPPING BATHS

The general principles of cattle dipping are similar to those of sheep dipping but on a correspondingly larger scale.

The cattle are assembled in a collecting yard, from which they pass through a triangular crush pen, from which they are admitted in single file into the entrance race. There they are urged to plunge into the bath. During their passage through the bath they become completely and thoroughly wetted with the dip. They find their feet on the exit slope, and pass into the exit or draining race and out at its open end.

The action is continuous, and the animals soon become accustomed to the routine, requiring very little persuasion to go through the various stages of the operation.

The drainings flow back to a sump, where solid matter, manure, etc., are strained out, and the wash then runs back into the bath, thus avoiding waste.

The site selected for the construction of a cattle dipping bath should be on slightly sloping ground, to prevent the settling of stagnant water round the bath during heavy rains. Preferably it should be near the homestead, and in proximity to a good water supply. In setting out the position of the bath, the latter should follow the direction of the natural slope of the ground, the exit being on the higher ground, so as to ensure that the drainage from the exit race shall be towards the bath.

Before starting the work of excavation a trial hole about 10 feet deep should be sunk to ascertain the nature of the sub-soil. A loose sandy formation is undesirable, as it is liable to move or settle, particularly beneath the exit slope, with result that cracking of the bath may ensue and cause leakage after the bath is built. For a similar reason, a heavy clay sub-soil should be avoided if possible.

The choice of materials for the building of a dipping bath will be determined to a large extent by local conditions as to costs and availability of supplies. The majority of cattle dipping baths are built of reinforced cement concrete, and in the long run they have proved

to be the most durable, serviceable, and generally the cheapest to construct and maintain. Very excellent baths may, however, be built of stone, rubble, brick, galvanised iron, and wood. The last two materials necessarily are perishable, and should not therefore be employed unless no other material is available. If bricks be used, they should be either hard burnt (non-porous) bricks, or, if otherwise, they should be faced with Portland cement. The same applies when a porous stone is used. Concrete baths should be constructed with care, precautions being taken to ensure that the placing of the concrete is done without interruption

1. The Steep Slope and Sudden Drop at Water Level.

2. The Level Entrance with Small Steps and Sudden Drop.

3. The Gradual walk-in Entrance with no Sudden Drop.

Fig. 114.—Diagram illustrating three types of "take off" for cattle dipping baths.

and that the work is kept moistened until the cement has absorbed sufficient water to ensure that it sets properly. The reinforcing material for concrete cattle dipping baths is usually in the form of barbed wire, laid in the body of the work, and so disposed as effectually to tie it together. This is a great safeguard against cracking and separation at the junctions of walls, floors, etc. For the construction of the yards and races, squared timber is required, which may be of sound pine or any hard native wood, but rough timber with projecting knots, splinters, etc., should be avoided as likely to cause injury to animals. For constructional details the reader is referred to the many published designs and specifications issued by various government departments and by dip manufacturers.

In selecting a particular design of bath, it is well to bear in mind

the object that it is required to accomplish., Primarily, it must secure complete if only momentary immersion. The animals must plunge in. and *under* the dip.

Three forms of take-off for cattle dipping baths have been advocated :—

1. The steep slope and sudden drop at water level.
2. The level entrance with small steps and sudden drop.
3. The gradual walk-in entrance with no sudden drop.

Of the three forms of take-off illustrated in Fig. 114, numbers 1' and 2 provide the best results, for the reasons explained hereafter.

The gradual walk-in entrance shown at No. 3, although favoured by some, is not to be recommended, as there is an absence of sudden drop, which is essential if the animal is to receive a complete overhead wetting. No. 2 has a practically level entrance with small steps leading to a sudden drop into the tank. This arrangement enables the animals to steady themselves for the plunge, and thus prevents the possibility of accidents by slipping, which may result in a fractured leg. Every beast goes under and receives a thorough wetting. There need be no fear of losing dip through backwash if the back step is made six inches high. No. 1 take-off is equally satisfactory, provided that the surface of the steep slope is well roughened to give the animals a sure grip for the steady plunge. The angle of the slope should be such that the beast plunges head first.

Shape and Dimensions of Cattle Dipping Baths. Sheep dipping baths are usually built with diverging sides, but experience has shown that for cattle dipping baths a cross section such as is shown in Fig. 115 best serves the purpose and at the same time economises dip. The vertical upper part of the side walls to a large extent prevents the dip being splashed over the sides. Also, it is found that with this section of bath there is less risk of long-horned animals getting jammed when under the liquid, a thing that is liable to occur in baths having walls diverging above the dip level.

As already mentioned, the primary object in dipping cattle is to secure complete immersion, length of immersion being of less importance than is the case in sheep dipping. The question therefore which should determine the minimum length of the bath is the distance which an active and vigorous animal can jump. The bath should be of such a length that there is no risk of the most active animal jumping and landing on the exit slope of the bath, which might mean broken legs. There is, however, one other consideration to be taken into account. A very short bath means a small capacity, and, if larger numbers of animals are to be dipped at short intervals, it would rapidly become

SECTION ON THROUGH SUMP-HOLE

SECTION AT A

BATH

EXIT RACE

A

CRUSH PEN
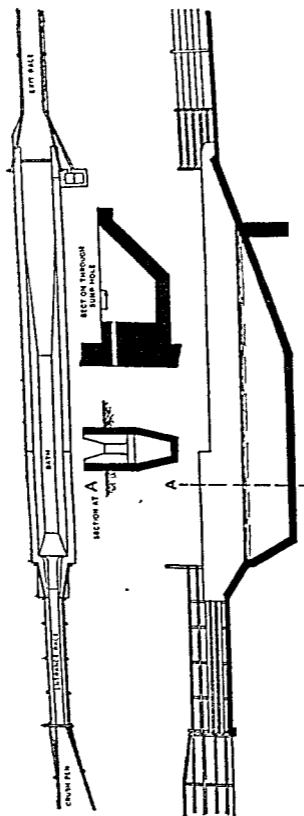
FIG. 115.—Cattle Dipping Bath with exit race.

foul and need renewing frequently. The length of the bath, therefore, should depend also on the number of cattle to be dipped. For the smallest herds the length of the horizontal floor of a cattle bath should not be less than 15 feet.   To obtain adequate immersion whilst allowing cattle to swim freely through the bath the length of this horizontal floor should be at least 24 feet.

Obviously the capacity of a bath may be increased by deepening it without affecting its efficiency, but, as the same object can be attained by lengthening it, the latter seems to be the better plan. A depth of 7 feet below dip level meets every requirement.

At the entrance end of a cattle dipping bath the side walls should rise at least 6 feet above the dip level to prevent the animals jumping the walls and to prevent splashing over when the animals are plunging into the bath. Towards the exit slope the height may be reduced by 2 feet.

For cattle dipping baths an exit race is preferable to a draining floor. Like the draining floor, the exit race should fall towards the dipping bath and provision be made for the drainings to be returned to a sump, from which, after straining and sedimentation, the dip is returned to the bath. The width of the exit race should be 3 feet, or sufficient to allow the cattle to pass through in Indian file. The length of the exit race should be sufficient to allow the dipped animal the drain completely before it leaves. A length of 120 feet meets the case.

As cattle dipping baths are used at short intervals over long periods, it is necessary to prevent rain water from getting into the bath, and also to check evaporation of the wash. Some kind of roofing is, therefore, desirable. This need not be an expensive affair, since a suitable covering may be erected with hard-wood poles and thatching grass. When constructing the roof care should be taken to allow sufficient walking space on one side of the bath, so that prompt assistance can be rendered to any animal which may be in difficulty whilst going through the bath.

Spraying Cattle. Although dipping is generally the most effective method of destroying ticks on cattle, there are circumstances which may make it impracticable to install a dipping bath, as, for instance, when the herd is so small that the expense is not warranted. Moreover, with the newer insecticides, better results may often be obtained by using a fresh wash of known concentration in the form of a spray than by dipping in a wash which has been made up for some time, is dirty and of unknown strength. The principal drawbacks to spraying are its higher cost for labour, and the opportunities it presents for
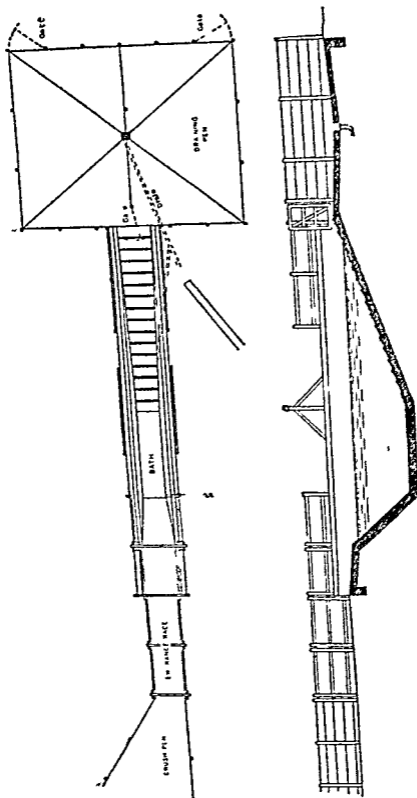
FIG 115.—Cattle Dipping Bath with exit race

·careless work. Hand spraying, to be effective, must be done with great ¬thoroughness, because if any parts of the animal escape being wetted ¬the ticks on those parts will survive the treatment Proper supervision ·of the operation is therefore necessary
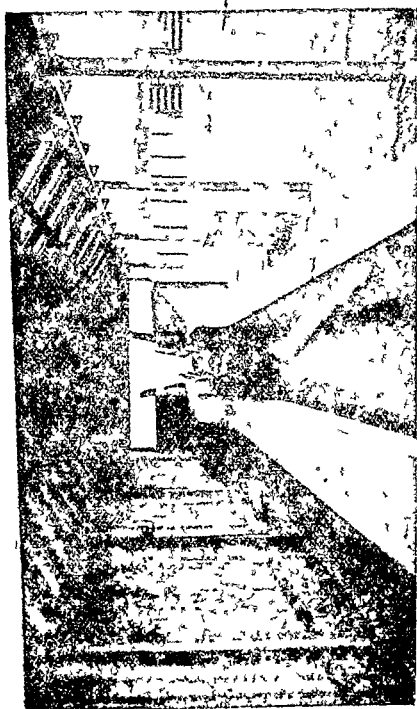
Fig 117—Cattle Dipping Bath   View looking towards the entrance race   Note the raised sides at the entrance to retain the splash as the cattle plunge into the bath   A side wall and roof protect the bath from exposure to sun and rain   On the right is a concrete mixing tank which communicates with the bath by an underground pipe

Experience has shown that spraying is a practical proposition for ¬herds of up to 200 head with their followers Adequate control of the animals is essential and this is best obtained by using a crush-race designed for the purpose One recommended arrangement is that in which there are two races each holding ten cattle, opening off the same ·collecting pen and used alternately so that the spraying can be carried

on as a continuous process, one race being filled whilst the cattle in the other are being sprayed

The pump used should be capable of maintaining a steady pressure of 100 lbs per square inch and an output of half a-gallon per minute A hollow cone type of spray is best and an important point is a trigger control which enables the spray to be turned on and off at will

A more elaborate device for cattle spraying is the spraying machine (Figs 118 and 119), which was introduced to minimise labour and increase efficiency The machine has the advantage of portability, so that it may quickly be taken to an area threatened with an outbreak of disease, thereby precluding the necessity for removing the animals from that area When permanently installed, the spraying machine should be
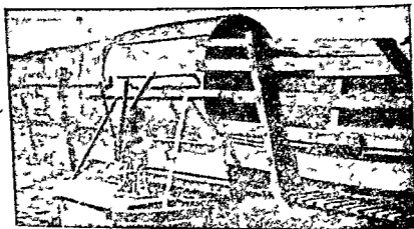
FIG 118 —The Cooper Spraying Machine The spraying tunnel is fitted with a series of pipes carrying numerous spraying nozzles The spray jets impinge on the animal from above from the sides and from below To the left is the force pump, standing on the dip storage tank

fitted with a collecting pen and races as for use with the dipping bath The spraying machine consists of a short tunnel of appropriate cross section constructed of sheet metal At intervals along the tunnel, pipes furnished with nozzles are attached to the wall A storage tank and pump are fixed alongside the tunnel The floor of the tunnel is in the form of a tray, in which the drainings collect and pass through a pipe to a strainer and so return to the storage tank

DIPPING ACCIDENTS

There is little danger of any toxic effects resulting from the use of benzene hexachloride and DDT* but accidents can occur with other dips particularly those of the arsenical and phenolic groups

*Jolly, D W (1952) Toxicity of DDT and BHC for Domestic Animals
Vet Rec., 64 76

Where manufactured dips are used in strict accordance with the maker's instructions, accidents are exceedingly rare. When they occur the cause can generally be traced to abuse of the dip, faulty mixing, or the use of faulty appliances. Excessive strength of a dip may be avoided by having the dipping bath accurately gauged and by reasonable care in measuring out the quantities of the concentrated dipping material

Fig 119 —The Cooper Spraying Machine End view, showing the machine in operation.

and the water. Such operations should always be supervised by some responsible person.

In sheep dipping it is best to start operations with a freshly-mixed bath, but if a residue of dip is carried over an interval in the dipping operations, then the greatest care should be taken in replenishing the bath, in order to secure that errors do not arise. Mistakes are liable to happen in dippings carried out under the Sheep Scab (Double Dipping) Order of the Ministry of Agriculture (Great Britain), when a second dipping must be carried out at an interval of not less than eight and not more than 14 days after the first dipping. In such cases it is not unusual to retain the residual wash from the first dipping and to replenish this at the second dipping. If an arsenical dip is

—V.H. 24

used at both dippings the strength of the residual dip must be reduced by the addition of an equal quantity of water, to give the half strength required for a second dipping at the prescribed interval   In this case the second dipping must not be carried out less than ten, nor later than 14 days after the first dipping   During the interval rain water may have obtained access to the dipping bath, diluting the dip and reducing its efficient strength, or evaporation of water may have occurred, with a corresponding concentration of the dip   If a note was made at the cessation of the first dipping of the level (by gauge mark) of the residual dip in the bath, the necessary adjustments can be calculated   If uncertainty exists, then the residual wash should be thrown away and a fresh bath mixed   With an accurately gauged bath a record can be made of the dipping level at the cessation of the first dipping operations and adjustments made accordingly when the time comes for replenishment

Where arsenical powder sheep dips are concerned a prevalent cause of accident is imperfect mixing of the dip   In preparing a powder dip for the bath, very little water should be added at first, and the dip should be worked first to a thick paste and then thinned down to a creamy consistency before the material is poured into the bulk of water in the dipping bath   The principle involved is that which applies to the mixing of dry powders generally with water, e g , cocoa, starch, or flour   If an excessive amount of water is poured on to the powder in the first instance, aggregates of powder are formed, wetted on the outside but containing dry powder within, and no amount of stirring will break these down   When such an imperfect mixture is poured into the dipping bath, the imperfectly wetted dip floats as a thick frothy scum on the surface, and the first animals that pass through the bath carry off this scum on their backs often with serious results

In the case of the carbolic dips, the use of a hard or brackish water for dilution may lead to a breaking of the emulsion with a separation of tar acids and tar oils, which float on the surface and are similarly carried off on the backs of the first sheep that pass through the bath

Other common causes of dipping accidents are overdriving of the animals immediately before or after dipping, overcrowding in the drain ing pens, or enclosing the dipped animals in unventilated sheds   Sheep, and particularly rams, in fat condition are especially susceptible to the effects of dipping and call for exceptional care, especially when the operation is conducted in sultry weather   Where the animals are put into the bath by hand, each should be lifted on its rump on to the end of the bath and allowed to slide gently downwards into the dip   As it leaves the dipper's hands, a forward push should be given to ensure that the animal is back uppermost   Before immersing the head,

the animal should be allowed to recover from the shock of the sudden immersion.

Arsenical Poisoning after Dipping.   Arsenical poisoning may result from absorption through the skin, by ingestion of the dipping wash, or by inspiration of dipping wash into the lungs.

The amount of arsenic that can be absorbed through the healthy and intact skin is inappreciable, but if the skin becomes inflamed by contact with excessively strong solutions, then rapid absorption may occur.   Arsenic is also readily absorbed through the raw and inflamed areas of skin which are found in sheep that have been subject to maggot fly attack, and also through skin wounds, shear cuts, etc.

Where arsenical poisoning by absorption through the skin has occurred, evidence of this can invariably be found in the presence of purple reddish patches of oedematous skin on the back and loins. When the skin is removed from the carcase, corresponding discoloured areas may be found on the flesh side of the skin, and there may be an accumulation of clear yellow or blood-stained serum in the subcutaneous tissues.   In post-mortem examinations care should be taken not to confuse the skin discoloration caused by hypostatic congestion with the lesions of arsenical poisoning by absorption.   Where arsenical absorption through the skin has occurred, the internal viscera will show more or less of the usual symptoms of arsenical poisoning.   When the arsenical poisoning is a result of ingestion or inspiration of arsenical solutions, the internal symptoms will be those usually associated with arsenical poisoning, but the skin lesions will be absent.   In all cases of suspected arsenical poisoning, particularly where the poison has entered by the alimentary canal or the respiratory passages, post-mortem findings should be confirmed by chemical analysis.

Where arsenical poisoning occurs after dipping, the animal shows a state of extreme depression, with drooping ears, and a disinclination to move, and, if it survives for a few hours, may scour.   In fatal cases death generally occurs within 24 hours of dipping.   Animals that survive for 48 hours generally recover.

Phenolic Poisoning after Dipping.   Where poisoning occurs after dipping in coal tar creosote or other phenolic dips, the poison may be absorbed through the skin or may enter the body by swallowing of the dip or inspiration into the lungs.   The onset of symptoms is usually slower than is the case of arsenical poisoning.   The affected animals look depressed and show a disinclination for movement.   The respiration becomes rapid and laboured, and the characteristic symptoms of pneumonia develop.   The visible mucous membranes are cyanosed, and the breath may have a pronounced phenolic odour.   In

fatal cases the affected animals generally pass into a comatose state, with a sub-normal temperature, and die in a paralysed and unconscious condition. Deaths rarely occur within 24 hours of dipping, but may continue for seven days or even more after dipping. The post-mortem findings are those of a general hyperaemia, with a more or less intense inflammatory condition of the lungs and the bronchial and tracheal mucous membranes.

Disposal of Waste Dip Washes. On account of their toxic nature, the safe disposal of waste dip washes is a matter that demands consideration.

It is obvious that such materials must not be discharged directly into a stream, river or pond, or in such a place that there is the slightest risk of them finding access to wells or underground water storage reservoirs or cisterns.

The most satisfactory arrangement is to construct a sump or soakaway pit adjacent to the dipping bath and to discharge all waste dip into this sump. The size and depth of the sump will depend upon the quantity of waste dip that has to be disposed of at any one time. For small sheep dipping baths where it is unlikely that the dip residues amount to more than 100 gallons (approximately 16 cubic feet), a pit 3 feet square and 4 feet deep (36 cubic feet) should be ample. It is usual to fill the pit with large stones to prevent falling in of the sides and when this is done allowance should be made for the volume occupied by the stones in order to ensure that the capacity of the sump is sufficient to take the waste dip without overflowing. A cover of wooden boards or corrugated iron sheeting should be placed over the sump when not in use.

The arsenic in arsenical dips is quickly rendered inert by precipitation in an insoluble form by contact with lime salts, iron oxides and other common constituents of soils. Investigations have shown that even where soak-away pits have been used for the reception of arsenical dip wastes for prolonged periods, the arsenic penetrates to a very small extent into the surrounding soil. In one particular instance in which soil analyses were made, no arsenic was found outside a zone of 9 inches from the walls and floor of the pit.

Where the soil is too impervious to make the use of a soak-away pit practicable, then the waste dip may be run into a pit and the arsenic precipitated by the addition of lime or a solution of ferrous sulphate. The insoluble arsenate settles to the bottom, and the supernatant clear liquid, which is now harmless, may then be allowed to run off. A few shovelfuls of soil may be thrown over the sediment in the pit as an additional precaution.

REGULATORY ACTIVITIES BY THE STATE
IN ANIMAL DISEASE CONTROL

THE control of contagious disease in animals is of such vital importance, not only to the agricultural industry but also to the food needs of the whole of mankind that nearly all countries have adopted legislative measures to deal with the major scourges. As far as Great Britain is concerned, its insular position is of very great value in controlling the introduction of animal disease from abroad and many of the official regulatory measures are designed to consolidate the natural advantages of our island situation.

The earliest legislation for the control of animal disease in Great Britain was aimed at the control of cattle plague. In 1746 an Order in Council was passed declaring this disease infectious and prescribing the slaughter of infected beasts, disposal of carcases and bedding, and the cleaning and fumigation of sheds.*

Subsequent outbreaks of cattle plague during the latter part of the eighteenth and early part of the nineteenth centuries were dealt with by similar Orders in Council. In the eighteen-forties, severe outbreaks of sheep-pox occurred and in 1847 and Act of Parliament was passed empowering the Queen in Council to prohibit the importation of sheep, cattle and other animals or to admit them after quarantine. An Act of 1848 was designed to prevent the spread of contagious disease among sheep, cattle and other animals and contained powers to regulate the movements of animals and meat.

The powers conferred under these Acts however were insufficient to deal with the widespread outbreaks of cattle plague which occurred in 1865 and the disease was not brought under control until the Cattle Diseases Prevention Act of 1866 was passed. This Act compelled local authorities to slaughter affected animals and disinfect premises which had then to be left unoccupied for 30 days before re-stocking. By September 1867, cattle plague had been stamped out and the experience gained in the control of this disease and of sheep-pox led to the introduction of the Contagious Diseases (Animals) Act, 1869, which conferred more extensive powers upon the Privy Council and the Local Authorities to deal with these diseases and with contagious bovine pleuro-pneumonia and foot-and-mouth disease.

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* Francis, J. (1948). The Contributions that Quarantine, Sanitary Measures and Eradication can make to Preventive Medicine. Vet. Rec. 60, 361.
† Francis, J. (1948). Op. cit.

Despite increased control over the importation of cattle, there were other introductions of rinderpest in 1872 and 1877 but in neither case did the outbreak reach serious proportions. Extensive epizootics of foot-and-mouth disease and pleuro-pneumonia occurred, however, and the Contagious Diseases (Animals) Act of 1878 resulted in the imposition of more stringent measures. In 1884 an Act was passed prohibiting the importation of cattle from many European countries where disease was prevalent.

The Diseases of Animals Act 1894. The Diseases of Animals Act 1894 consolidates and amends existing legislation. Later Acts are the Act of 1896 which amends certain portions of the 1894 Act relative to the landing of foreign animals, the Act of 1903 concerning Sheep-scab, the 1909 Act which gives authority for the payment of fees to veterinary surgeons for the notification of certain diseases, and the 1910 and 1914 Acts which deal with the exportation of unfit horses. The Act of 1922 deals with the importation of Canadian and Irish cattle ; that of 1925 makes provision for repayment to the Local Authority of part of the compensation payable by Local Authorities in respect of animals slaughtered for tuberculosis (now dealt with under the Agriculture Act of 1937), and the Act of 1927 repeals certain sections of the primal Act and increases the penalties for offences. The Act of 1935 extends the application of the original Act to poultry and also introduces measures to control the manufacture and the sale of veterinary therapeutic substances.

The Agriculture Act 1937. Under Part IV. of this Act the powers of Local Authorities to carry out a veterinary inquiry as to the existence of suspected disease were transferred to the Ministry of Agriculture and these powers are now exercised by the Animal Health Division of that Ministry. The Act also gives power to the Minister to expend money for the eradication of diseases of animals, it extends the power of the Minister as regards the slaughter of animals and it also confers powers on the Minister with regard to diseases of poultry. The latter include measures to promote the breeding and distribution of stocks of poultry that are free from disease and the provision of free veterinary services for owners of approved breeding stations.

The Diseases of Animals Act 1950. The Diseases of Animals Act 1950 consolidates the Diseases of Animals Acts, 1894 to 1937 (including the relevant parts of the Agriculture Act 1937) and certain other enactments relating to diseases of animals including the Exportation

of Horses Act, 1914 and 1937, the Importation of Animals Act, 1922 (Section 2), the Importation of Pedigree Animals Act, 1925, Part I. of the Animals Act 1948 and section 2 of the Dogs Act 1906.

Main objects of the Acts. Generally speaking, the Acts impose upon the Minister of Agriculture and Fisheries, as the central authority, the duty of devising and putting into operation measures for the control and eradication of contagious diseases amongst animals in England, Wales and Scotland. They confer upon the Minister wide powers to make Orders for these and other specified purposes, including :—

   (a) The declaration of infected places and areas ;

   (b) The prohibition or regulation of the movement of animals into, out of, or within such places and areas, and of the exposure of animals at markets, sales and exhibitions ;

   (c) The control of the importation of foreign animals, carcases, fodder, etc., for the purpose of preventing the introduction of disease from without ;

   (d) The muzzling and control of dogs ; and

   (e) The protection of animals and poultry from unnecessary suffering during transit by land or sea.

Thus, while indicating the general lines of the procedure to be adopted, the Acts empower the Minister to prescribe the details by administrative Orders which have the full force of an Act of Parliament.

The main endeavours of the Ministry, so far as animal disease is concerned, are to prevent the entrance into this country of certain diseases, and to keep under control such as are here epizootic or en-zootic and to work for their ultimate eradication. With these aims in view the Acts are formulated for the compulsory notification of these diseases ; for the immediate isolation or segregation of the diseases or suspected animals ; to provide for the diagnosis of suspected disease by specially trained persons ; for the slaughter of diseased or in-contact animals where this may be necessary, and for the payment of compensation ; for the apprehension and punishment of offenders against the Orders issued by the Ministry ; for the systematic inspection of markets, sales, fairs and exhibitions, etc., and for the seizure therein of any "diseased" or in-contact animals where this may be necessary ; for regulating the transit of animals under all conditions, both for safeguarding the country from disease and also for the humane treat-ment of animals when in transit ; for controlling the import of animals and things which may introduce disease, and for the inspection at the ports of disembarkation of living animals and for their slaughter while isolated.

Duties of Local Authorities Under Part IV of the Agriculture Act, 1937 all veterinary duties under the Acts were transferred from Local Authorities to the Ministry of Agriculture whilst, generally speaking, the administrative duties remained with Local Authorities The more important of the duties retained by the Local Authorities are as follows —

1 The promulgation of the Ministry's Orders

2 The power to make certain local regulations *e g*, concerning the dipping of sheep

3 The appointment of inspectors (*i e*, non veterinary inspectors, many of whom are police officers) whose duties include the serving and enforcement of notices defining Infected Places and requiring detention and isolation of animals or the dipping of sheep in certain cases, the supervision of the cleansing and disinfection of infected premises in certain cases, the making of arrangements for the disposal of the carcases of diseased or suspected animals other than those slaughtered by the Ministry the issue of licences for the movement of animals in infected, controlled or scheduled areas under conditions prescribed in the Orders

4 The local enforcement of all the general Orders, including those made for the prevention of animals from unnecessary suffering during transit These Orders provide for control of the movement of imported animals, paving, cleansing and disinfection of livestock markets and lairs, cleansing and disinfection of vehicles used in the transport of animals, boiling of specified animal foodstuffs, destruction of hay and straw packing material and disposal of meat wrappers, the regulation of the fitting of ships used in the carriage of livestock and of the construction of railway and road vehicles for the transport of animals, records of the movement of certain classes of livestock.

In England and Wales the Local Authorities are (1) for Boroughs where the population exceeds 10 000, the Borough Council, and (2) for the residue of each administrative county, the County Council For the City of London the Local Authority is the Common Council which also acts as the Local Authority for the County of London where the Acts relate to Foreign Animals For Scotland the Local Authorities are (1) the Magistrates and Town Councils of each burgh which contains a population of more than 20,000, and (2) the County Council for each county and for residual burghs

Growth of the State Veterinary Service —The Diseases of Animals Act of 1894 gave power to the Government to take certain measures for the pre-

vention and eradication of disease in animals, and in these measures most important duties and responsibilities were imposed on Local Authorities. These duties were largely administrative, but for diagnostic inquiries private veterinary practitioners were employed. Certain diseases, as for instance foot-and-mouth disease, were chiefly controlled by a centralised staff, and others, for example anthrax, by local authorities. Other diseases again, such as sheep-scab, were dealt with in part by the centralised and in part by the local authorities' staffs, although the Government through its veterinary officers exerted supervisory control over all notifiable diseases. Under the Diseases of Animals Acts every Local Authority was obliged to appoint one or more veterinary surgeons as "veterinary inspectors" for carrying out the necessary diagnostic inquiries into reported or suspected disease. Most of these "veterinary inspectors" were private veterinary practitioners who held part-time appointments under the Local Authorities, but early in the twentieth century several municipalities and later on a few counties appointed whole-time veterinary staffs for this purpose. Lanarkshire was the first to appoint a whole-time county officer in 1910. Several other Scottish counties followed suit, while in 1913 a whole-time officer was appointed in Cumberland.

With the coming into force of the Milk and Dairies legislation in 1925 and 1926, the importance of the Local Authority veterinary services grew rapidly. The veterinary duties imposed by this legislation were performed at first by the existing staffs, although one whole-time officer was appointed for Glamorganshire in 1925. The West Riding of Yorkshire was the first to take the matter up seriously, and appointed a whole-time staff in 1927 and 1928, consisting of nine veterinary officers. From this time onwards many other counties in Great Britain formed or increased the veterinary services in their areas, and this gave rise to a number of highly organised departments which rapidly became an integral part of the county administration.

. One result, however, was that the various Acts and Orders were administered in a variety of ways, some authorities being most meticulous in the manner they carried out their obligations to the State and to the public, while others, and unfortunately quite a large number, merely did the minimum insisted on by the law. While the Ministry of Agriculture and Fisheries had a staff of upwards of 100 veterinary officers stationed in different parts of the country, they were able to assume only a somewhat mild control over the work of the local authorities as regards the Diseases of Animals Acts and Orders, but had no powers at all over the duties prescribed by the Milk and Dairies legislation.

In 1934 the Report of the Cattle Diseases Committee of the Economic Advisory Council brought the whole position of the veterinary Services of the country to official notice. It thus became apparent that the only way to ensure uniformity of control, and more especially to carry out any general measures for the eradication of disease, was to institute a State Veterinary Service for all official veterinary duties, for it was rightly claimed that "disease knows no administrative boundaries."

This was followed by the passing of the Agriculture Act of 1937. This Act provided for measures for eradication of disease rather than mere suppression, and Section 21 of the Act reads—"The Minister may, with the approval of the Treasury, expend such sums as he thinks fit with the object of eradicating as far as practicable diseases of animals in Great Britain........."

This Act also, with the view of getting rid of divided authority, transferred the whole of the purely veterinary duties under the Diseases of Animals Acts and Milk

and Dairies legislation imposed on Local Authorities to the State under the Ministry of Agriculture and Fisheries   Machinery was set up to make the necessary adjustments, and all whole-time veterinary officers of Local Authorities who were carrying out any of the transferred duties were invited to apply for inclusion in the State Veterinary Service   The vast majority of them were thus incorporated in this new service, leaving only a few Local Authority veterinary officers for non transferred duties   The day for the transfer was fixed for 1st April, 1938, when the new service assumed full authority

The section of the Ministry which deals with this work is known as "The Animal Health Division" and is administered by a lay administrative and a veterinary professional staff   The staff consists of an Assistant Secretary as head of the Division, assisted by an administrative staff at Headquarters   The professional staff consists of one Chief Veterinary Officer at Headquarters assisted by two Deputies and one Chief Superintending Veterinary Officer who is also head of the fields staff, and a number of Superintending and Divisional Officers who control the work both at Headquarters and in the field   While the Headquarters of the Ministry are in London, there is a sub-office in Edinburgh where a Deputy Chief Veterinary Officer has direct contact with the Department of Agriculture for Scotland on matters relating to the Animal Health Division of the Ministry

For administrative purposes, the United Kingdom is divided into 20 areas, each in charge of a Superintending Veterinary Officer   Each Superintending Veterinary Officer is responsible for supervising a number of Divisions, each of which corresponds to a county or a group of small counties in which is included any county borough in England and Wales, or burgh in Scotland   Each Division, of which there are 78, is in charge of a Divisional Veterinary Officer who has under him a number of whole-time Veterinary Officers, a number of veterinary practitioners acting as local Veterinary Officers on a part time basis, and a clerical staff

The Divisional Veterinary Officer is in much the same position as the Chief Veterinary Officer of a county used to be under the Local Authority, and is responsible for keeping in close touch with the Local Authorities in his Division, and for arranging for all diagnostic enquiries and veterinary work in his district, including the supervision and tuberculin testing of the Attested and tuberculin tested herds, and the examination of cattle in the milk producing herds   His duties also include giving help and advice with regard to poultry

Included in the field staff of the Ministry is a number of veterinary officers under a Superintending Officer who are especially detailed for duty at the Ports These officers are responsible for the supervision of the importation and exportation of animals at the various ports   In connection with the export of cattle, the Ministry operate quarantine stations in London Glasgow and Liverpool, where pedigree cattle, sheep, goats and swine can be quarantined

The staff of the State Service also comprises the laboratory and research side. This staff is under the Director of the Ministry's Laboratory at Weybridge   In this laboratory research and laboratory investigations into pathology and epizootology of diseases routine laboratory diagnosis, manufacture of sera, vaccines and other biological products are carried out. There is also a large laboratory near Edinburgh equipped and run especially to deal with poultry in Scotland

The Veterinary Investigation Service, which was taken over by the Ministry in 1946 forms a link between the laboratory and the field staffs of the Divisions There are 13 Veterinary Investigation Centres in England and Wales at each of which is stationed a Veterinary Investigation Officer and one or more Assistant Veterinary Investigation Officers

The duties of the Veterinary Investigation Officers include assistance to veterinary surgeons in the diagnosis of disease and the investigation of particular disease-problems in the locality.

NOTIFIABLE DISEASES

Under the Diseases of Animals Act of 1894, now consolidated in the Diseases of Animals Act, 1950, notification of the existence or suspected existence of certain diseases is required and the Minister of Agriculture has power to add to this list such other diseases as he may think advisable. At the present time the following are listed :—

    Anthrax in four-footed mammals.
    Cattle plague in ruminants and swine.
    Epizootic lymphangitis in equine animals.
    Foot-and-mouth disease in ruminants and swine.
    Glanders and farcy in equine animals.
    Parasitic mange in equine animals.
    Pleuro pneumonia in cattle.
    Rabies in ruminating and equine animals, swine, dogs and cats.
    Sheep-pox in sheep.
    Sheep-scab in sheep.
    Swine fever in swine.
    Tuberculosis (certain forms only) in cattle.
    Fowl pest in poultry.

Several of these diseases have not appeared in Great Britain for many years :—cattle plague since 1877, epizootic lyphangitis since 1906, glanders and farcy since 1928, pleuro pneumonia since 1898, rabies (other than in imported dogs detained in quarantine kennels) since 1922 and sheep-pox since 1850.

Though information concerning the Orders applicable to some of the notifiable diseases is given in the following pages, it must be clearly understood that in no case is there given an exact rendering of any Act or Order; what are considered to be the leading features have been extracted, in some cases more fully than in others. In all cases of doubt the actual Order should be consulted.

General Responsibilities of Stockowners and Veterinary Surgeons Relating to Notifiable Diseases. The following responsibilities imposed by statute have general application to most of the Notifiable Diseases.

Notification of Disease or Suspected Disease.—This must be made by the owner of the animal or the occupier or person in charge, and by the veterinary surgeon in attendance, to the police of the district. Notice must be given without undue delay.

Presumption of Knowledge of Disease—A person required to give notice if charged with failure to carry out his obligation shall be presumed to have known of the existence of the disease, unless and until he shows, to the satisfaction of the Court, that he had not knowledge thereof and could not with reasonable diligence have obtained that knowledge.

Separation of Diseased Animals.—Every person having a diseased animal shall, as far as practicable, keep it separate from animals not so diseased.

Facilities and Assistance to be given for Inspection, Cleansing and Disinfection.—Persons in charge of diseased animals are required to give every facility for the execution of the above, and must not obstruct or in any way hinder inspectors or other officers in doing their duty.

The Acts and Orders impose upon stock-owners and the public generally an obligation to afford inspectors and police all necessary facilities for the performance of their duties including the collection and penning of animals for examination and testing by veterinary officers, the giving of required information as to the movement of animals to and from their premises, the production of licences, registers, records, etc.

Prohibition of Exposure or Movement of Diseased Animals.—It is unlawful to expose a diseased or suspected animal in a market, sale-yard, fair, or other public or private place where such animals are commonly exposed for sale ; to place an affected animal in a lair or other place adjacent to or connected with a market, sale-yard, etc., or where such animals are commonly exposed for sale ; to send a diseased animal on a railway, or on any canal, inland navigation or coasting vessel ; or to allow one on a highway or thoroughfare, or on any common or unenclosed land or in any insufficiently fenced field ; or to graze one on the sides of a highway ; or to stray on a highway or thoroughfare or on the sides thereof, etc.

Digging up Carcases.—No person may dig up the carcase of an "animal" that has been buried without permission from the Ministry of Agriculture.

General Procedure on Notification.—When the existence of any of the notifiable diseases is suspected the police constable who receives the report must immediately notify the veterinary officer appointed by the Minister (in most cases the Divisional Veterinary Officer) and an Inspector of the Local Authority. In the case of the following diseases he must also immediately notify the Ministry Head Office by telegram :—swine fever, foot-and-mouth disease, cattle plague, contagious bovine pleuro-pneumonia, epizootic lymphangitis and sheep-pox.

The Inspector of the Local Authority on receiving notification of the suspected existence of disease has certain duties to perform which include transmission of the information to the Divisional Veterinary Officer (if this has not already been done by the police constable) and reporting the information to the Local Authority. In addition, when cases of anthrax, glanders and farcy, rabies and foot-and-mouth disease are suspected, the Inspector of the Local Authority must also inform the Medical Officer of Health for the district.

ANTHRAX

Anthrax is an acute affection caused by a specific sporulating organism, *Bacillus anthracis*. Its contagious character has been known since 1836, and the etiological significance of the bacilli was first demonstrated by Davaine in 1865. Sporulation, which does not occur either in the living or dead body, takes place under aerobic conditions, *i.e.*, where there is a supply of free oxygen. The bacilli are soon destroyed when buried in heated manure. The optimum temperature at which sporulation takes place is 30° C. (81° F.) when there is a plentiful supply of oxygen. The maximum temperature at which it will occur is 42° C. (107.5° F.) and the minimum temperature is approximately 16° C. (60° F.) As the spores are extremely resistant to desiccation, remaining viable for 18 years or longer, and withstand dry heat at 140° C. for longer than 2 hours, and are, furthermore, very resistant to disinfectants, it is evident that the utmost precaution needs to be taken to prevent the escape of virulent blood from the body. The spores are, however, less resistant to moist heat, a ten minute exposure to boiling water being enough to destroy them. On the other hand, bacilli in the begetative form are readily destroyed by direct sunlight, heat, putrefaction, desiccation and by disinfectants of moderate strength. If an infected carcase is not cut the bacilli are destroyed as soon as putrefaction commences, quickly in the deeper parts and later (1 to 3 days) in superficial·parts. Bacilli may be avoided in faeces and urine and in blood from lungs, etc., during life and are also present in the milk of infected cows shortly before the death of the animal.

Symptoms of Anthrax. The disease shows itself suddenly. It is usually fatal within 48 hours. Anthrax does not in Great Britain usually spread with rapidity from animal to animal, but it may affect a number of swine at the same time if they have been fed on anthrax flesh or organs. A beast which a short time before appeared to be well is found dead or in a dying condition. *Frequently blood*

oozes from the nostrils and the anus In cattle there are no typical symptoms, but in horses and pigs the throat region is often swollen. After death the carcase rapidly becomes bloated and blood exudes from the nostrils and anus

Incidence and Sources of Infection. All mammals are susceptible to anthrax, and of the domesticated animals, cattle are most frequently affected, then pigs, horses, sheep and dogs in the order given. The disease is also known among fur bearing animals in captivity, which are fed chiefly on raw flesh During 1938 in Great Britain 7 outbreaks were reported on mink farms involving the death of 315 animals out of a population of about 1290

The period of incubation is from 1 to 3 days, but may be as long as 12 to 14 days, mortality is high

When a case of anthrax is definitely diagnosed, an exhaustive inquiry is held into the possible source of infection, and thus information is gained which may prove of value in preventing further outbreaks In his Annual Report for 1929, the C V O, Ministry of Agriculture, made an analysis of the records kept for a period of ten years —1919 to 1928—and showed that in Great Britain during the period of ten years there were 5512 outbreaks, an average of 551 per annum, with a range from 239 (1919) to 734 (1924) Of these 5512 outbreaks, 1061 occurred on premises infected within the previous five years, and 4451 on non infected premises Of the outbreaks on previously clean premises, the following were regarded as the probable source of infection —

Use of imported foods	67 8 per cent.
Use of imported foods and artificial manures	13 7 ,,
Use of artificial manures of animal origin	4 3 ,,
Effluent from tanneries, etc , infecting streams	1 6 ,,
Feeding infected carcases and offals, etc , to pigs, etc	0·5 ,,
Use of "shoddy" as litter	0·3 ,,
Not improbably anthrax, but disease not reported	1 1 ,,
No explanation available	10·7 ,,

It should be realised that the official returns indicating the source of infection are based on circumstantial evidence, it being very difficult, and in fact in many cases impossible, to recover the organism from the suspected food, though this has occasionally been successfully accomplished. Soil-dirtied foods, such as China beans, are to be looked upon with suspicion Imported foods may be contaminated on ships if infected hides are carried on top of the food, grain sweepings from holds should also be treated as a possible source of infection. Infection may also be carried by flies and by carrion-feeders

The extent to which the disease may be transmitted by imported feeding stuffs is emphasised by the reduction in the number of outbreaks in recent years when, as a result of the war, the quantities of feeding stuffs and other imported materials have been considerably reduced. The following table shows the number of outbreaks during 1938/1948.

	Number of confirmed outbreaks	Number of Animals affected
1938	830	1,235
1939	699	792
1940	564	677
1941	399	470
1942	372	414
1943	283	320
1944	189	204
1945	119	135
1946	95	98
1947	121	139
1948	118	128

The contamination of pastures with effluent from tanneries has been particularly evident in the valley of the River Nene in Northamptonshire where heavy losses of stock have occurred. In 1943 the number of animals which died of anthrax in this area was 48 but since that date the use of a spore vaccine for preventive inoculation of animals in the area has considerably reduced the number of fatalities.

Pastures contaminated with the blood of animals infected with anthrax may remain dangerous for many years, hence the cutting of the carcase of a beast which is suspected to have died of the disease must be avoided at all costs.

Preventive Measures. Anthrax is a notifiable disease, and the disposal of carcases of animals suspected to have died of the disease is under the control of the Local Authrotity, being supervised by and carried out to the satisfaction of the Veterinary Officer of the Ministry of Agriculture. Effective destruction of the infected carcases, soiled litter and dung is of the first importance. Under the Order carcases may be either buried or cremated (see later, Anthrax Order of 1938). There is little danger of subsequent infection of other animals if burial is immediate and deep and the carcase has not been mutilated. Whereas hides of anthrax carcases must on no account be slashed or cut in any way, the carcases of animals affected with any of the other notifiable diseases must be slashed before burial so as to make the hides useless.

The method to be adopted in dealing with an anthrax-infected carcase depends upon the locality and circumstances under which it is found. In all instances the carcase must be strictly isolated and prompt measures taken to prevent the spread of the infective material.

such as pulmonary discharge or exudations from the anus, vagina, etc,
and to prevent access to it of dogs, vermin and, if possible, flies until
such time as the grave or crematorium is ready for its reception
Should the animal be one of a number of cattle in a byre, those
adjacent should be removed immediately and placed by themselves, not
only to prevent them becoming infected, but also so that they may be
kept under observation   If obtainable, some absorbent such as peat-
moss, sawdust, etc, should be scattered thickly on any discharge to
prevent it running down the dung channel or across the stall   Dung
recently passed should be collected from the channel and placed along
side the carcase until it can be dealt with   The channel behind the
stall should then be well soaked with carbolic acid or other strong
disinfectant   Precautions should be taken to prevent infected dung
from being thrown out as manure, and infective material must be
prevented from travelling down the channel into the drainage system.
The carcase should be covered with sacking soaked in some disinfec-
tant to prevent or discourage flies from feeding off the infective dis-
charges   It is better to leave the carcase in the byre until it can be
finally disposed of than to drag it outside, where it would be more ex-
posed to attacks by vermin and dogs   Should the carcase be in a field,
temporary fencing of hurdles stuffed with furze will keep off dogs and
foxes during the night   The removal of the carcase for disposal must
be done with the greatest care   The rectum, vagina, nostrils, and mouth
must be stopped with wool or tow soaked in carbolic acid or other suit-
able disinfectant   This is not easily done, but neglect to take every
precaution to prevent discharges from soiling the ground during transit
of the carcase is a serious matter   The carcase should be handled as
little as possible , farm labourers are not able to appreciate the grave
risks run from manual contact with the blood stained quarters or
head, and the whole proceedings should be strictly supervised.   Ropes,
or other combustible materials, which have been utilised in the shifting
of the carcase, should be burned   The carcase is best conveyed to the
place of destruction on some sort of trolley (a hurdle provided with
runners is often the best obtainable), and should be securely fastened to
it   Owing to the difficulty of completely closing the mouth and nostrils,
and to the frequency with which virulent blood flows from these
orifices when the carcase is on the trolley, the head should be bent
backwards over the shoulder so as to keep it at a high level and be
fixed in that position with ropes tied to the hurdle   It is a good plan
to enclose the head in a sack containing some absorbent material
soaked with disinfectant   Some Local Authorities provide rubber
bags for this purpose   If the head is left to trail along the ground
infection of the soil is certain to follow   It is impossible to take too

much care during the transit of the carcase to the place of its destruction. The ease with which infection may be spread is shown by the following remarks by the C.V.O. in his annual report for 1914 :— "A horse which had been worked as a chain horse to a lorry employed in carrying hides in the Liverpool docks died of anthrax. A horse which had been used to drag a carcase of a cow which had died of anthrax from the shippon to the grave died of the disease."

All litter, dung and scrapings from the stall and its immediate vicinity, after a thorough soaking with disinfectant, must be carefully collected and buried or burned with the carcase. Having removed the most obvious and easily removable dirt, the entire stall, manger and surroundings must be disinfected.

The veterinarian may have to decide on the course of action when one of a number of animals grazing in a field is found to have died of anthrax. Clearly, the first thing to do is to fence off the carcase with hurdles, woven-wire or a couple of strands of fence wire ; barbed wire should not be used for this purpose owing to the liability of persons being scratched when working with it. The rest of the cattle should be confined by fencing in a small portion of the same field for observational purposes and to reduce the risk of widespread infection of the pasture resulting from the previous infection of any of the beasts. It is obviously unwise to move such potentially infective animals to fresh pastures.

Vaccine and Serum Therapy. When several animals in a herd are affected, or when the disease appears periodically on a pasture, indicating infection of the field, vaccination of the apparently healthy animals is worth considering. In recent years a spore vaccine has been used with success in parts of Great Britain, *e.g.*, the valley of the River Nene in Northamptonshire, where there is particular danger of outbreaks of anthrax owing to contamination of pastures with tannery effluent. The use of hyperimmune serum is indicated when in-contact animals show evidence of infection by rise of temperature.

Anthrax in Man. In man the disease is contracted, as a rule, through inoculation of cutaneous abrasions on the hands and arms when the carcase of an animal that has died of anthrax is skinned, or when such an animal is slaughtered and dressed. Cattlemen, butchers and knackers are liable to infection under these conditions. Anthrax is also conveyed to people by the handling of infected hides or their products. Infection may also occur by inhalation, especially when the fleece or hide is dry (wool-sorters' disease).

—V.H. 25

Disinfection of Wool, Hides, etc. In order to minimise the incidence of anthrax among persons handling infected wool, hair and hides, various methods of disinfection or of preventing infection have been devised The disinfection of these materials is rendered specially difficult on account of the ease with which they are damaged by heat or by chemical solutions, while the anthrax spores present are usually protected by albuminous matter

For the disinfection of *wool and hair* the "Duckering" process, employed at the Government Wool Disinfecting Station at Liverpool, has proved to be very satisfactory A Home Office Departmental Committee has reported (1928) that no objection can be taken to the quality of wool disinfected by this process The method is based on Eurich's observation that a 2 per cent solution of formaldehyde (5 per cent formalin) at 100° F kills naked anthrax spores in 30 to 35 minutes The bales of wool or hair are placed on a moving platform, the bale coverings are removed by hand and the bundles are opened up by machinery and passed through a series of *five* baths, designed first to cleanse, and then to disinfect the material In the first place, the wool is submitted to the action of a ½ per cent solution of sodium carbonate in order to remove albuminous coating of the spores The second bath contains a ½ per cent solution of soap and a small amount of free caustic alkali Blood clots and excrement are softened by treatment in these baths, and the wool is now passed between rollers in order to break up softened masses of blood clot, etc In these preliminary processes the wool is cleaned, much dirt being removed mechanically and by the solvent action of the soap and alkalis The wool is then passed through two tanks, each containing a 2 per cent solution of formaldehyde In a fifth bath it is washed in water in order to remove excess of formaldehyde, which may otherwise remain on the wool or hair in sufficient quantity to inconvenience workers who are subsequently handling it in manufacturing processes The wool is then dried in a current of hot air, cooled and re-baled In this process the only stages in which handling is necessary are in removing the canvas coverings from the bales prior to disinfection and in rebanding the disinfected material. The baths are maintained at a temperature of 102° to 105° F , and the strength of the solution is kept constant by the addition of the necessary constituent at a rate which compensates for the loss occurring during the process of disinfection. The time of exposure in each bath is ten minutes The efficiency of disinfection is checked by bacteriological examination of the materials being treated before and after their subjection to the "Duckering" process

An Order in Council (1921) made under the Anthrax Prevention Act, 1919, prohibits the importation of Egyptian wool and Indian goat

hair, except at the Port of Liverpool, where on arrival they are taken
charge of by H.M. Customs and transferred to the Government Disinfecting Station for treatment.

No method which is both bactericidal and commercially satisfactory
has so far been evolved for the disinfection of *hides*. Two methods
that have been widely used are the Schattenfroh and Seymour-Jones
processes.

In the Seymour-Jones method the hides are immersed for 24 hours
in a solution containing 0.02 per cent. mercuric chloride and 1 per
cent. formic acid, and are then placed for 1 hour in a concentrated
solution of common salt. It has, however, been reported that anthrax
spores may survive 14 days' exposure in the perchloride-formic acid
solution.

The Schattenfroh, or pickling process, consists in soaking the hides
for 2 days in a solution containing 2 per cent. hydrochloric acid and
10 per cent. common salt at a temperature of 20° C. (68° F.).

Attempts have also been made to disinfect hides during the
"liming" stage in the process of tanning by adding sodium sulphide
to the lime bath. The work of Robertson[*] suggests that treatment of
anthrax-impregnated threads in a sulphide-lime bath containing 1 per
cent. of sodium sulphide crystals ($Na_2S,9H_2O$) and 1.2 per cent. lime
(CaO) for 10 days at a temperature of 23° C. (73° F.) destroys the
majority of the anthrax spores and that such a treatment does not
cause damage to hides or skins. Agitation of the fluid appears to
accelerate disinfection. Experiments with packs of *infected hides*
show that "sulphide liming" with intermittent agitation for 8 hours
at 32° C. and then for 4-5 days allowing the temperature to fall off
gradually leads to successful disinfection without damage to the hides.[†]

In consequence of the presence of anthrax infected hides in the
liquors used in tanning leather, viable anthrax spores may be present
in the effluents from tanneries and may reach the streams and fields.
Up to the present, however, no efficient and economical method has
been evolved for destroying the anthrax spores in these discharges.

Legislation. Anthrax Order, 1938.—Notification of the suspected
existence of disease in any animal or carcase must be made to a police
constable, whose duty it is immediately to transmit the information to
the Veterinary Officer of the district appointed by the Minister of
Agriculture (usually the Divisional Veterinary Officer) and also to

[*] Robertson, Madge E., December, 1931. *Jour. Internat. Soc. Leather Trades' Chemists.*

[†] Jordan Lloyd, Dorothy, and Robertson, Madge E., December, 1930, *Journ. Internat. Soc. Leather Trades' Chemists*, and Robertson, Madge E., 1930, *B.L.M.R.A. Reports.*

give information to the Inspector of the Local Authority who shall inform the Medical Officer of Health   Any veterinary surgeon who, in the course of his practice, suspects the existence of disease shall also notify the police

Precautions to be Taken —The occupier of the premises must prevent access of animals or poultry to the suspected animal or carcase or to any part of the premises which may have been exposed to infection by the animal or its discharges   He must retain on the premises any suspected animal or carcase and any sheep, cattle, goat or swine which have been in the same shed, building, field, etc , or in any part of the premises contaminated by discharges from a suspected animal   He must also disinfect, as soon as possible, with an approved disinfectant, any place where the suspected animal or carcase has lain or where its blood has escaped

The skin of a diseased or suspected carcase must not be cut or anything done to cause effusion of blood, except by a veterinary inspector of the Ministry of Agriculture or a veterinary surgeon acting on behalf of the woner of the carcase, and in either case so far only as may be necessary for the purpose of obtaining suitable material for microscopical or cultural examination   It is to be noted that this clause definitely gives a veterinary practitioner authority to incise the skin of a suspected carcase for the purpose of making a diagnosis on behalf of his client , that is to say, if a veterinary practitioner is requested by his client to make a post-mortem examination of an animal found dead, it is the right and proper thing for him to examine for anthrax as a routine measure

The milk produced by any diseased or suspected cow or goat must not be mixed with other milk, and must be boiled or otherwise sterilized, and any utensil in which such milk is placed before sterilization must be sterilized with boiling water before any other milk is placed therein

It is to be noted that the precautions detailed above automatically become operative before the serving of a form (Form A) which declares and defines an infected place   This notice has to be served by an Inspector of the Local Authority on receiving intimation of the suspected existence of the disease   The limits defining the infected place have to be such as will prevent the risk of infection spreading, but must not be unnecessarily wide

Veterinary Inquiry —The Veterinary Officer acting on behalf of the Ministry of Agriculture has to make a diagnosis by a microscopical examination of the blood   If, in his opinion, the animal is not affected with anthrax, he must give a certificate to that effect, and Form B is served by the Inspector of the Local Authority, which

removes the restrictions imposed by Form A. If, on the other hand, the Veterinary Officer is not satisfied that anthrax does not exist, he gives a certificate to the Local Authority to that effect, stating that the case is one of *suspected* anthrax ; he has no authority to state that anthrax definitely exists. The Veterinary Officer, if he suspects the occurrence of anthrax, has to forward suitable material to the laboratory of the Ministry at Weybridge for diagnostic purposes, together with a report of his examination. The material which he has to send is the slide upon which his diagnosis was made, an unstained film, which has been dried in the air but not with heat, and a sterile swab dipped in the blood and enclosed in a suitable glass or metal container. In the case of a horse or a pig subcutaneous tissues may be required. The material has to be suitably numbered, and this particularly applies, of course, where more than one carcase has been examined. The package must comply with Post Office regulations ; that is to say, the material must be sent in a box of wood, leather or metal, marked on the outside "Anthrax for Diagnosis," and it must be sent by *letter post*. The report must not be enclosed with the material but posted separately.

Precautions by the Local Authority.—Where the Veterinary Officer certifies the case to be one of "suspected anthrax," the Local Authority must direct an Inspector to carry out *forthwith* such disinfection as may be necessary and to arrange for the destruction of the carcase in the manner prescribed by the Order. In view of the risks involved, this action must be taken without awaiting the result of the examination of the material sent to the Ministry's laboratory.

Rules for an Infected Place.—Those concerning the prevention of access of animals and poultry to the diseased animal or carcase, detention of suspected animals, disinfection, and prohibition of the cutting of skin, have already been detailed. Horses, asses, mules or dogs which are not diseased or suspected may be taken out of or into an infected place. Other animals may not be moved out of the premises except with permission in writing of an Inspector of the Local Authority, and then only to the nearest available slaughter-house or to other specified premises. Litter, dung, utensils, hurdles, etc., must not be removed from an infected place except by permission in writing from an Inspector of the Local Authority. The milk produced by diseased or suspected animals has to be treated as before described.

Disposal of Carcases.—The carcase has to be destroyed by fire on the premises or on the nearest available premises suitable for the purpose (see page 324 for description of methods of cremation), or the Local Authority may have the carcase disinfected and then taken to suitable premises for destruction by exposure to a high temperature

or by chemicals, where the circumstances do not permit of the disposal of the carcase by any of the foregoing methods, it may be buried in some suitable place to which animals would not have access, sufficiently removed from any dwelling house, and at such a distance from any well or water course as to preclude any risk of the contamination of the water. The carcase has to be buried at a depth not less than 6 feet below the surface of the earth and with a layer of lime not less than 1 foot deep both above and beneath it. Before the carcase is removed for burial or destruction, all the natural openings must be effectively closed with tow or other suitable material soaked in an approved disinfectant.

Where in the case of a four footed animal which is kept in a zoological collection it is impracticable to dispose of the carcase unless it be cut, such cutting may be done, but only with the permission and under the supervision of the Veterinary Officer of the Ministry of Agriculture.

Cleansing and Disinfection—Except in the case of zoological collections, the Local Authority has to bear the cost of cleansing and disinfection. This has to be carried out in all parts of any shed, stable field, etc, which have been in contact with the diseased animal, and on every utensil, hurdle, etc and every cart, vehicle, etc, which have been in contact with the diseased animal. Disinfection has to be carried out as follows—Premises must be given a preliminary thorough soaking or drenching with an approved disinfectant, this to be followed by scraping (where practicable) and, where necessary sweeping, all the scrapings sweepings, dung etc, must be removed and burned or otherwise destroyed. If destruction is not practicable they must be mixed with quicklime and removed from contact with animals, after the preliminary soaking with disinfectant, scraping, sweeping etc, a thorough washing or scrubbing with water is required, to be followed by a final coating or washing with an approved disinfectant. Any litter, dung, fodder, etc, likely to spread the disease has to be disinfected thoroughly, and if it is impracticable to disinfect it, it must be burnt or destroyed. The occupier of any place and the owner of anything liable to be cleansed and disinfected have to grant facilities for the purpose

FOOT AND MOUTH DISEASE

Foot and mouth disease is an acute and highly infectious disease of cloven hoofed animals caused by a filterable virus and characterised by the production of vesicles in various parts of the body but most fre-

quently on the mouth and feet. Immunological experiments have been shown that at least three different types of virus exist. These have been termed the "O," "A," and "C" types, to which the majority of strains can be assigned, though variants and intermediate types occur (F. & M. Res. Com., Fifth Progress Report, 1937). The immunity resulting from recovery after infection with one type of virus does not confer any protection against subsequent infection with either of the other two types. An animal recovered from an attack produced by the "O" type virus is immune for a considerable time (over 32 months) to further infection with "O," but can be infected with "A" type virus within a few weeks of recovery from the "O" infection. Conversely, an animal recovered from infection with "A" type virus is then immune to "A" but can be infected with "O." Clinically the disease produced by all three types is indistinguishable.

Considerable research work has been done on foot-and-mouth disease in this country under the direction of The Foot-and-Mouth Disease Research Committee, appointed by the Minister of Agriculture in 1924. Much has been learned concerning the ability of the virus to survive outside the animal body, the susceptibility of various animals and the effect of disinfectants on the virus. Cattle, sheep, goats and pigs are susceptible ; dogs and cats can be infected by inoculation, but natural infection has not been established in these species. Rats and hedgehogs can be infected, and disease can spread from rat to rat, and hedgehog to hedgehog, by contact, without inoculation (Fourth Progress Report, pages 24-25). The occurrence of foot-and-mouth disease in a wild hedgehog has been reported, together with experiments which suggest that natural infection may be transmitted from cattle to hedgehogs, and from hedgehogs to cattle (Fifth Progress Report, 1937). Man is seldom affected, though cases have been described by Pape (1921) and Trautwein (1930). The apparent occurrence of the disease has been recorded by De Long (1912) in three foals which were turned out to graze with affected cattle. The guinea-pig is very susceptible to inoculation, but disease does not spread by contact. Rats have been found affected by foot-and-mouth disease on pemises where the disease existed in cattle, pigs, etc. (Fourth Progress Report, page 23).

The survival of the virus outside the animal body depends on various factors, *viz.*, temperature, condition of atmosphere, and material on which the virus is deposited. A low temperature and a dry atmosphere, *e.g.*, frosty weather, favour survival, while sunlight fairly rapidly renders the virus inert. On hay and bran the virus has been shown to remain active for eight to fifteen weeks while on cow's

hair it remained active for four weeks at ordinary temperatures (Second Progress Report, page 11) It has been shown by Andrews (Fourth Progress Report, page 13) that virus in blood dried on glass, iron, zinc, tile, brick, or wood at ordinary temperatures only survived for two or three days, while on hide, leather from a boot, or rubber from a gum boot, the virus survived up to 80 and 102 days respectively. It has also been demonstrated that virus survives in the bone-marrow of frozen cattle and pig carcases for 76 days and in chilled carcases for at least 42 days (Second Progress Report, page 45) Virus has also been recovered from the bone marrow of pig carcases after dry or wet salting after 42 days The virus is rapidly destroyed by heat, water at 60° C destroys virus rapidly, while boiling water destroys it instantly Virus present in milk will lose its infectivity after boiling, and also after pasteurisation of the milk In dried milk powder, the virus would be inactivated by the temperature reached during drying by the roller process, which is commonly used, but might survive the spray process, in which little heat is used, unless the milk had been previously pasteurised (Fifth Progress Report, page 14) Of chemical agents the most effective in destroying the virus are caustic soda and caustic potash, which may be used in 1 or 2 per cent solution, formalin in 1 per cent. solution, and washing soda in 4 per cent. solution when heated to 50°-60° C

Incidence. Foot and mouth disease is widely distributed throughout the world It is prevalent on the continents of Europe, Africa, Asia, and South America The disease is not normally present in Australia, New Zealand and North America but there have been extensive outbreaks in Mexico in recent years

In the years 1937-39 there existed on the continent of Europe an epizootic of foot-and-mouth disease which caused immense loss, and which exemplifies the need for constant vigilance in the diagnosis of the disease The epizootic started in May, 1937, and is believed to have been introduced into France by the importation of infected sheep and pigs from Algeria and Morocco There is evidence which suggests that the disease was overlooked at the time of importation, chiefly because many of the sheep were affected with foot-rot According to Galloway,* a study of the spread of the disease on the Continent indicates that Holland, Belgium and Germany were infected from France, the epizootic subsequently spreading rapidly northwards and eastwards, and that the particular strains of virus involved, irrespective of type, were of a kind which spread rapidly The further march of

*Galloway, I A (1940) *Vet Rec* 52, 45-47

the epizootic was obscured by the outbreak of war in 1939. The following table, after Galloway, shows the numbers of outbreaks (infected premises) during the European epizootic —

Country	1937	1938	1939	Total 1937-39
Germany	36,908	644,676	27,218	708,802
Yugoslavia	14	147,913	297,164	445,077
France	160,373	216,582	19,100	396,055
Roumania	0	3,678	249,999	255,677
Czechoslovakia	0	225,794	4,256	230,320
Poland	1	225,625	2,056	227,681
Holland	93,522	92,473	21,801	207,796
Belgium	63,254	37,943	7,928	109,125
Denmark	12	29,902	7,124	37,038
Italy	272	7,101	14,897	21,998
Switzerland	273	7,779	5,694	13,766
Sweden	0	3,266	2,815	5,075
Great Britain	187	190	99	476

Foot-and-Mouth Disease in Great Britain. Foot-and-mouth disease first appeared in Great Britain in 1839, and was present continuously from that date until 1886, with the exception of a few months freedom at the end of 1879. Probably not less than 7,000,000 animals were attacked during this period. According to the report of the Departmental Committee appointed in 1911, "in ten out of twenty-one years from 1892 onwards the disease has existed in Great Britain, the total number of outbreaks in that period being 158, but of these 133 occurred during the first ten years and only twenty-five during the last eleven years." The disease cropped up again in 1892, when there were 95 outbreaks, involving 4,767 animals. Since 1892 the importation of cloven-hoofed animals from abroad has been prohibited. In 1893 there were only 2 and in 1894 3 outbreaks, and the disease was then absent until 1900, when 21 outbreaks were recorded. The country was free for six years previous to 1908, when the disease appeared in Edinburgh, and from that date there have been outbreaks each year with the exception of the years 1909 and 1917. In 1912 there were 83 outbreaks. During the years 1922-23-24 the disease was very prevalent in Great Britain, and cropped up throughout England, Scotland and Wales with alarming rapidity. The incidence then decreased for a number of years until 1937 when an increase was recorded, possibly consequent on the severe outbreak on the continent of Europe already mentioned. In the war years, 1940-45, there is evidence that the increased number of outbreaks was associated with the feeding of swill to pigs (see Cabot, page 378).

The following table shows the outbreaks in the United Kingdom since 1922 —

Year	No of Outbreaks	Year	No of Outbreaks
1922	1 140	1936	67
1923	1 929	1937	187
1924	1 440	1938	190
1925	260	1939	99
1926	204	1940	160
1927	143	1941	264
1928	138	1942	670
1929	38	1943	27
1930	8	1944	181
1931	97	1945	129
1932	25	1946	54
1933	87	1947	104
1934	79	1948	15
1935	56	1949	15

Since foot and mouth disease is not endemic in Great Britain, the question naturally arises as to how infection is introduced into this country Sir Daniel Cabot then Chief Veterinary Officer, Ministry of Agriculture in an important article dealing with the epizootiological aspect of the disease (Cabot 1945*) lists the methods by which infection may be brought to this country as (a) the introduction of infection by untraced means, (b) the importation of diseased animals, and (c) the introduction of infection by chilled or frozen meat imported from infected countries Cabot continues by explaining the circumstances in which the disease has occurred in Great Britain in recent years —

(a) The introduction of infection by untraced means —Outbreaks occur in this country in which no obvious channel of infection can be determined Our insular position eliminates the day to day traffic in persons animals and goods which cannot be effectively controlled over land frontiers It is obvious that land frontiers form no barrier to the spread of foot and mouth disease and we know to our cost that the Channel and even the North Sea can be overcome , the location of out breaks with a negative history of origin suggests that the European Continent is the source of infection. A typical illustration of this is the series of outbreaks which occurred in the eastern and south-eastern counties and in the counties of Dorset, Hampshire Somerset and Wiltshire during the autumn of 1937 and the early months of 1938 In this series there occurred 249 outbreaks in which the disease resembled that then raging in France and the Low Countries and which was destined to ravage Central Europe and it also conformed in type (Type O)   There is no doubt that the disease in England originated on the Continent, but what is uncertain is the proporti on of outbreaks which were initial and the proportion that arose as secon dary Possibly two-thirds or more of these outbreaks were due to spread with n the country

* Cabot, D (1945) *Vet Rec* 57 375 377

"The first of these outbreaks was notified on 16th October, 1937, and it is significant that in this month in other years, outbreaks of obscure origin have arisen. This time factor, together with the localities involved, the arrival of flocks of migrant birds (starlings especially) and the routes of migration, all suggest strongly that these birds are mechanical carriers of infection. In the great majority of such cases, the initial outbreaks occur among cattle at grass. Incidentally, there is a sharp contrast in the course of the disease in England where prompt notification was followed by the rapid application of stamping-out measures and rigid control of movement of stock and its course on the Continent where the authorities were powerless to check its dissemination.

"Whilst the cumulative experience over a number of years leaves little doubt that birds may introduce disease, this factor does not operate every year as obviously the danger is related to the disease position at the resting places of the migrant flocks on their way to this country, and as this varies from year to year, so also does the incidence of such outbreaks vary in this country.

"On the other hand, it has been suggested that there are other means whereby infection is introduced from the Continent, but the history of disease in this country does not support these suggestions.

"(b) *Importation of diseased animals.*—The prohibition of importation of livestock from infected countries reduces this danger to a minimum. Normally, the importation of cattle, sheep and swine is restricted to Ireland, the Isle of Man, the Channel Islands and Canada. Occasionally, disease has been introduced into Great Britain from Ireland through the shipment of animals after the appearance of disease in that country, but before the facts became known to the authorities, when further shipments were, of course, suspended during the emergency. The last occasion in which disease was so introduced was in 1942. Disease was found in two landing places in this country, but the prompt application of restrictions prevented the movement of stock out of the ports and disease was confined to those two landing places.

"(c) *The introduction of infection by chilled and frozen meat imported from infected countries.*—Observations in the field having indicated the association of initial outbreaks with kitchen waste and more directly, on one occasion, with imported carcases, experiments were conducted at Pirbright, the result of which proved the possibility of survival of virus in carcases held at the refrigeration temperatures at which the trade in imported meat is conducted. The virus was shown to survive under chilled conditions for as long as the meat is marketable under those conditions and for 100 days (not end-point) when the meat is frozen. During the war, all meat is imported in the frozen state or processed.

"To exemplify this risk, *I shall discuss the history of the initial outbreaks that occurred during 1944, when an exceptionally large number of invasions were recorded. Actually the number is 93, of which 13 occurred during the months of January to July inclusive, the number rapidly rising in August and continuing at a high level until the end of the year and later. Broadly, these outbreaks were characterised by common features and there was a marked absence during the winter months of the type of outbreak discussed earlier, the origin of which is attributable to Continental sources.

"The outstanding feature of these 93 outbreaks is the fact that in 78 cases the disease started in pigs. In most of these cases, pigs were the only animals on the premises.

"In practically every case, raw swill was brought to the premises for pig feeding, where in accordance with the Regulations it should have been boiled for an hour before being fed, and animals should not have been allowed access to it before it

was boiled. Swill from various sources was concerned in these initial outbreaks; swill from canteens, restaurants, private households and Service depots, but swill from United States camps was not incriminated The United States establishments draw their meat supplies from the North American Continent, where foot-and-mouth disease does not exist. But whilst kitchen waste, which includes scraps of meat and vegetable trimmings which so often are in contact with joints of meat and meat juices in kitchens, serves as a vehicle of infection, the risk of introducing virus in meat imported from infected countries is not confined to the feeding of improperly treated swill to pigs as is demonstrated by the occurrence of a number of outbreaks on the premises of butchers who at the time were distributing South American meat In a few of these cases, the disease did not start in pigs, but in cattle which had access to meat-wrappers, etc , in the yards

"The activities of the Waste Food Board of the Ministry of Supply—with which are associated the Ministries of Food and of Agriculture and Fisheries—have resulted in the establishment, in populous areas, of central establishments where swill is either concentrated or boiled and then distributed to pig keepers It is merely in accordance with expectation that the feeding of centrally processed kitchen waste has proved to be safe and the absence of foot-and-mouth disease among pigs fed on swill distributed from these central treatment plants testifies to the signal service rendered to the agricultural community and to the nation by the provision of a very large and safe tonnage of pig food, much of which in its initial state, as judged by the use of swill taken to farms in the raw state, was capable of setting up disease It is to be borne in mind that when raw swill is brought to a farm, its cooking is not the only safeguard to protect animals, and there are many ways in which infection may be conveyed to stock unless all necessary precautions are taken. Hence, the principle of central treatment is essentially sound

"There are two further pieces of evidence In certain parts of the country, where fat stock is produced in sufficient quantity to provide the meat ration for the local population, a minimum of imported meat is supplied with the object of economising transport. In these areas there has been a practically complete absence of outbreaks Also a fatal form of the disease occurred in some localities in South America and was also found in this country, when a number of adult cattle died. This virus was identified as Type C, and, fortunately, though lethal, showed little power of diffusion

"The position may be summed up as follows —

"It has been shown experimentally that the virus will survive for months in frozen carcases

"During 1944 a large number of outbreaks occurred among pigs fed on kitchen waste and outbreaks have occurred, not always among pigs, on the premises of butchers distributing imported meat.

"During the same period, there has been a virtual absence of disease in those limited parts of the country which are chiefly self-supporting in meat, and on farms where only centrally sterilised kitchen waste was used for feeding pigs.

"The association of disease with the imported meat trade either directly on butcher's premises or indirectly by the taking of swill in the raw state to piggeries indicates without any question the source of infection during the past year

"The only countries infected with foot and mouth disease from which any meat was imported into Great Britain during the period under review were the South American Republics, and there seems no room for doubt that it was from these countries that our repeated infections were derived.

"Many of these initial outbreaks occurred in piggeries in built up areas, and, consequently, because of the paucity of livestock in such districts, there was little

opportunity for the disease to spread, and also relatively very few markets were involved. Other centres, however, proved more troublesome. During the year all three types of virus were identified."

Prevention and Control. Two methods are now in general use in the control and eradication of foot-and-mouth disease : (1) The slaughter method, which is adopted in Great Britain and in the U.S.A., and which has been used at various times in other countries ; and (2) the quarantine procedure, which is used in most European countries. Which of these methods is adopted depends upon prevailing conditions. In an island, such as Great Britain, the slaughter policy is the most practicable and in the end the most economic, but when a continental country with land frontiers is exposed to risks of repeated reinfection eradication by slaughter becomes impossible and other methods must be sought. The most logical of these is obviously some method of quarantine or segregation of infected stock, together with prophylactic measures to prevent the spread of the infection to susceptible animals in areas adjacent to those where quarantine restrictions are in force. It must be noted, however, that many European countries have regulations providing for the slaughter of affected animals, and which may be put into effect when this is believed to be the most efficient method of preventing extension of the disease.

In Great Britain the disease is notifiable under the Diseases of Animals Acts, and stock-owners and others must notify the police if they suspect the existence of foot-and-mouth disease among their stock.

Prevention.—Preventive measures against foot-and-mouth disease in Great Britain may be grouped under two headings :—(1) Measures adopted to prevent the introduction of the disease from abroad, and (2) measures adopted once the disease has been found to be present in the country.

From what has been previously said, and also from the Reports of various Departmental Committees on Foot-and-Mouth Disease, it is obvious that there exists the continual hazard of the disease being introduced from over-seas. The Government has, therefore, taken steps to prevent as far as possible, and without undue restrictions on trade, the introduction of disease from this source. A brief survey of the regulations in force at the present time will serve to show the more important ways by which disease might be introduced :—

(a) All cattle, sheep, goats, and all other ruminants and swine are prohibited from entering this country from abroad. A few countries are excepted, *e.g.*, Ireland, Canada, etc., but generally speaking the statement is correct. (Animals (Importation) Order, 1930, and Amending Orders.) *This prohibition of importation of susceptible species is*

undoubtedly the most important measure in the prevention of foot and mouth disease in Great Britain.

(b) Carcases of cattle, sheep, goats and swine are not allowed to be imported from the Continent of Europe. Fully-cured bacon and ham carcases are excepted, and hides are allowed to be imported on condition that they have been dried, dry-salted or wet-salted. This prohibition of carcases was put into force in 1926, when the infection was introduced into this country in fresh pig carcases from the Continent (Importation of Carcases (Prohibition) Order, 1926, and Amending Orders). The C.V.O. states in this connection in his Annual Report for 1926 (p. 4)—"The year 1926 was notable for the discovery in May of one of the most dangerous sources of re-infection from the Continent, namely, the importation of fresh carcases, and for the consequent enactment as from 2nd June of the embargo on Continental meat."

(c) Meat, bones, offal and other parts of the carcase of any animal, swill and any other broken or waste foodstuffs which have been in contact with meat, bones, etc., must not be permitted to come into contact with animals, and must be boiled (212° F. for one hour) before being fed to animals (Diseases of Animals (Boiling of Animal Foodstuffs) Order, 1947). The necessity of this restriction on food stuffs of animal origin becomes apparent when it is recalled that the virus of foot and mouth disease may remain active in carcases for as long as 72 days and that pigs can be readily infected by feeding with infected bones. The Foot and Mouth Disease Research Committee in their Fourth Progress Report, state in this connection:—"It has been shown that carcases of animals which have been killed during the infective period may contain deposits of active virus for long periods after being subjected to various pickling processes, and especially when the carcase has been kept at low temperatures. One well-established method by which pigs can become infected from such carcases is by feeding them with uncooked crushed bones. Meat scraps kept at low temperatures are also infective. This was found to be the source of the outbreak among pigs in California reported by Mohler (1929). In this case the pigs first received the meat scraps fifty seven days after the carcases had been shipped in South America. It is clear then that importation of infected meat or offals in a chilled or frozen state is a ready means by which infective material can be conveyed to this country, and that one way in which the infection may then be transmitted to farm animals is by the feeding of pigs with parts of the carcase, especially with the bones. Whether this undesirable event occurs or not depends on the state of the animals at the time and place where they are slaughtered and on how the carcases are disposed

of after arrival in this country. The dissemination of active virus by carcases of infected animals might occur from one part of the country to another, as well as by importation from abroad if cases of disease were overlooked." The statement of Cabot (1945), cited previously, also makes abundantly clear the dangers associated with the feeding of untreated swill to pigs.

Under the Foot-and-Mouth Disease (Disinfection of Road Vehicles) Order of 1941 any road vehicle used for the carriage of swill must be thoroughly disinfected with a 4 per cent. solution of sodium carbonate after use, and the carriage of swill in a road vehicle at the same time as feeding-stuffs, litter or anything else for use in connection with animals is prohibited.

(d) Imported meat must be wrapped in cloths of a prescribed pattern. Imported feeding-stuffs, fertilisers, etc., must *not* be packed in bags of this prescribed pattern. Feeding-stuffs, fertilisers, litter, etc., must not be packed in this country in meat wrappers as above. (Importation of Meat, etc. (Wrapping Materials), Order, 1932.) This is another necessary precaution against infection passing from imported carcases to animal feeding-stuffs, litter, etc., and hence to animals themselves ; and finally meat cloths must not be brought into contact with animals unless they have been boiled or otherwise sterilised. (Foot-and-Mouth Disease (Packing Materials) Orders, 1925 and 1926.)

(e) Foreign hay and straw are not permitted to be landed in this country unless as packing or manufactured straw. As virus can remain active for a number of weeks on hay or straw which may have been contaminated in the country of origin, the prohibition of landing is most essential. (Foreign Hay and Straw Order, 1912, and Amending Orders.) A further precaution, however, is necessary in regard to packing-hay and -straw which are allowed to land. All packing-hay and -straw in this country if not used again as packing must be destroyed, and must not be allowed to come into contact with animals. (Foot-and-Mouth Diseases (Packing Materials) Order, 1925 and 1926.)

(f) In June, 1938, an outbreak of foot-and-mouth disease occurred in Great Britain which was proved to have been caused by the injection into a cow of glandular extract imported from abroad. As this occurrence indicated the need for controlling the use of sera and glandular products for the treatment of animals susceptible to foot-and-mouth disease an Order, entitled The Foot-and-Mouth Disease (Sera and Glandular Products) Order, 1939, now prohibits the use of any such preparation, whether manufactured in Great Britain or abroad, unless the substance bears a label stating that its use for veterinary purposes is authorised under this Order. The Ministry of Agriculture state that "veterinary surgeons and others who, from time to time, treat

animals with preparations of these kinds, should, therefore, take care to see that all supplies of these substances are labelled in the manner required by the Order" Permission to attach the label will be granted in respect of *(a)* preparations manufactured from live animals in Great Britain or in a "non prohibited' country (Canada, U S A., Australia New Zealand, Eire Northern Ireland, the Channel Islands and the Isle of Man, all other countries are "prohibited' countries), or from animals slaughtered in Great Britain or in a "non-prohibited country, *(b)* preparations manufactured in Great Britain or elsewhere if the process of manufacture is, in the opinion of the Minister, lethal to foot and mouth virus, and *(c)* preparations obtained from animals not susceptible to foot and mouth disease

Control—As already stated, foot and mouth disease is notifiable in this country under the Diseases of Animals Act It is therefore compulsory for stock owners, persons in charge and veterinary surgeons to notify the police if they suspect the disease The law imposes serious responsibilities upon the owner or person in charge of animals Section 83 of the Diseases of Animals Act, 1950, states that 'he shall be presumed to have known of the existence of the disease or illness unless he shows to the satisfaction of the Court that he had not knowledge thereof and could not with reasonable diligence have obtained that knowledge' Clearly, therefore if in the exercise of reasonable diligence he calls in a veterinary surgeon, the full responsi bility for notification is passed to the latter under the Foot and-Mouth Disease (Amendment) Order 1938 Early notification of suspected cases is most important, stock owners and veterinary surgeons should not hesitate to report if there is the least suspicion of foot and-mouth disease If the suspicion is not confirmed no harm has been done by reporting, whereas on the other hand, if disease actually does exist and has not been notified the result may be disastrous The owner may have been visiting markets and other stock in the interval, and may convey disease elsewhere not to mention the fact that he may move stock off his premises in the belief that the illness among a few of his animals is trivial

Should a veterinary surgeon be called to a case and on examination suspect the disease he should inform the owner, disinfect himself as far as practicable before leaving the premises, and inform the police of his suspicions He should return home, completely change his clothing, and again disinfect his hands in a hot solution of disinfectant, at the same time making good use of a nail brush. On no account should he wear any article of clothing worn on his visit to the suspect when going to visit another case If disease is subsequently confirmed, the clothing worn at the time of visit to the infected place should be

disinfected as follows :—Boots should be washed with an approved disinfectant solution as hot as possible ; washable clothing should be steeped in disinfectant for twenty-four hours and then washed in hot water ; suits, etc., which cannot be washed should be disinfected by fumigation by the formalin-potassium permanganate method ; the clothes should be placed in a chest made as airtight as possible and formalin gas generated by passing formalin into a bucket in the chest containing potassium permanganate. When the bottle containing the formalin is placed in such a position as to allow its contents to flow on to the permanganate the lid of the chest should be closed down and left for twenty-four hours.

When disease is reported the State machinery for dealing with it is set in motion as prescribed by the Foot-and-Mouth Disease Order, 1928, and the Foot-and-Mouth Disease (Amendment) Order, 1938. The police inform the Local Authority and the Ministry of Agriculture and Fisheries by telegraph. Notice (Form A) declaring the premises an Infected Place is served on the owner, and the V.O. of the Ministry visits as soon as practicable. (No persons other than officials are allowed into or out of the premises, and such officials must wear rubber boots and overalls capable of being disinfected.) If he suspects the disease he signs a certificate to that effect and notifies the Chief Constable of districts within five miles of the Infected Place and sends a copy to the stationmaster of the nearest railway station. With the signing of the certificate (Form C) a five-miles area, radiating from the infected place, immediately becomes a standstill area. If the V.O. does not suspect disease he takes no action apart from seeing that the Infected Place rules (Art. 7, F. & M. Ord., 1928) are observed. The movement of livestock and personnel on and off the premises is subject to rigid control. The V.O. immediately communicates with the Ministry in London by telephone and if he is satisfied that the case is negative the Ministry issue instructions for the immediate withdrawal of restrictions. In a positive case the Ministry declare an Infected Area of approximately fifteen miles radius under the Foot-and-Mouth Disease (Infected Areas Restrictions) Order, 1938, and the area specified becomes subject to the conditions of this Order. These conditions include restrictions on the movements of all cloven-hoofed animals, the suspension of markets and sales of animals, the control of dogs and poultry and the prohibition of hunting and coursing. It is at the Ministry's discretion whether the affected animals are slaughtered or not. At the present time the Ministry as a rule slaughter the affected animals and dispose of the carcases by burial, fuel-shortage preventing the use of cremation. Contact animals are also destroyed but if they are apparently healthy the carcases are salvaged for food purposes. The byres,

pig sties and yards, etc , must be sprayed and soaked with disinfectant,
cleansed, and again disinfected with an approved disinfectant   A 4 per
cent solution of washing soda is used extensively   Foodstuffs which
are considered to be contaminated must be burned as well as litter
and sacks   Carts, etc , should be disinfected in the same way as the
byres   Churns, milk-cans, etc , should be disinfected with 4 per cent
solution of washing soda in water and finally scalded with boiling
water or steam.   The attendants' clothing should be disinfected by
the formalin potassium permanganate method   The surface layer of
manure in cattle pens should be removed and burned, and the re-
mainder sprayed with disinfectant   Hay and straw stacks should be
sprayed with a solution of one per cent formalin in water   Minett
(Third Progress Report, p 37) found that trussed hay could be effec-
tively disinfected by spraying with formalin solution , he also showed
that hay treated in this way could be fed to animals without any ill
effects   Grain and feeding stuffs exposed to lesser chance of infection
may be dealt with by fumigation with formaldehyde in a closed, and
as air tight as possible, room.   As regards disinfection of pastures, very
little can be done , in the summer, sunshine is the best disinfectant, and
pastures being uncovered will benefit greatly from it   In this con
nection the C V O , in his annual report for 1929, states   ' Time and
natural agencies alone are depended upon in the case of pastures since
disinfection is not practicable, and only the heavily contaminated parts,
such as gateways and the vicinity of the incineration pit, are
disinfected ''

The interval of time between the completion of disinfection and
the time of re admission of animals to the Infected Place is approxi
mately six weeks   Experience in this country has shown this to be a
relatively safe period   A few recurrences have taken place , in this con
nection it is interesting to note the words of Sir Ralph Jackson,
C V O , in his report for 1929, in which he summarises the recurrences
of the disease for the past twenty years (1909 1928) —"All the re
currences appear to be associated with buildings or with foodstuffs and
straw   In four cases it was reported that defective floors had probably
been responsible for the upkeep of the virus despite the fact that disin-
fecting solutions had been used on a very liberal scale on account of
the unsatisfactory hygienic conditions   The foodstuffs in most cases
consisted of a variety of provender, including hay, meals, cake roots,
and there were usually more or less abundant supplies of straw   In
some cases the hay was stored in a loft over the cow shed   Such
supplies of hay were contaminated by the attendants during the early
stages of an outbreak, and since the lofts were not air tight fumi-
gation was impracticable   Destruction was equally impracticable in

view of the large quantities found in these lofts. The usual practice was to spray with a formalin solution the parts of the store to which the attendants had access in drawing supplies for cattle. In only one case no foodstuffs remained after the cleaning of the premises after the first outbreak of the disease."

The Order prohibits the movement of any animal, including horses and live poultry, hares or rabbits and their carcases, out of an Infected Place, except under licence granted by the Ministry. Milk from diseased or suspected animals cannot be removed from an Infected Place and must not be fed to animals unless it has been boiled.

It is important also to note that dogs, cats and poultry on an Infected Place should be shut up or otherwise confined until disinfection of the premises has been completed.

For the complete list of restrictions imposed on the Infected Place the reader is referred to the Foot-and-Mouth Disease Order, 1928, and the Foot-and-Mouth Disease (Amendment) Order, 1938.

Control by Prophylactics. In Great Britain the success of the slaughter policy in stamping out invasions of the disease has undoubtedly justified its continuance as the most economic means of control. In countries where the disease is endemic, however, vaccination is resorted to. Waldmann's formolised vaccine, as used in Germany, is claimed to give an immunity lasting six to eight months and, more recently, a crystal violet vaccine has been employed extensively in South America.

SWINE FEVER

Swine fever (hog cholera) is a highly contagious disease of the pig caused by a filterable virus. The pig is the only animal susceptible to the infection. Available evidence points to the disease having been introduced into Britain from the Continent at a date prior to 1858.

Swine fever attacks pigs of all ages, but in many outbreaks the newly-weaned animals appear to be the most susceptible and have the highest death-rate in the herd, but this is not invariably so, and pigs of any age are liable to be attacked. The period of incubation is at least four and may be as long as ten to twenty days. The mortality varies greatly with the character of the outbreak, depending principally upon the virulence of the virus. In very acute outbreaks from 70 to 90 per cent. of deaths may be expected. The average mortality for all outbreaks is placed at about 30 per cent.

Methods of Spread. The virus is present in the blood and also in the faeces and urine, and it is through the agency of these excretions that the disease is spread. Infection occurs by ingestion. Once the disease is introduced into a piggery it is readily disseminated by

attendants carrying infection on their boots, brushes, shovels and the like. The disease may also be spread by rats, flies and birds. The chief method by which the disease is spread from one district to another is by the sale of infected "store" pigs, and particularly when "stores" pass through the hands of dealers. The passage of infected pigs through a market is frequently the cause of multiple outbreaks, the urine and faeces voided by the pigs in their pens and in the sale-ring infecting the boots of attendants and purchasers as well as the feet of pigs passing through the ring. It has been suggested that the use of food sacks returned from a piggery may be the means of spreading this disease; while this may be possible, it is doubtful if such sacks play an important part in dissemination. Swill containing waste pig products is a potential source of infection if the swill has not been boiled as required by the Diseases of Animals (Boiling of Animal Foodstuffs) Order of 1947.

Under the Regulation of Movement of Swine Order of 1950 and the Amending Order of 1950 the holding of a sale of swine in any market, fairground or sale yard is prohibited unless such sale is authorised by the local authority. These orders also place restrictions on the movement of swine from any market, fairground or sale yard or from any collecting centre used by the Minister of Food or from the premises of a pig dealer. The restrictions now apply to the whole of Great Britain.

Whenever swine fever assumes serious proportions the Ministry make a special "standstill" order over a certain area of the country for a few weeks or even months.

Incidence. The number of confirmed outbreaks of swine fever in Great Britain in the last two decades is as follows :—

Swine Fever Incidence			
Year	Number of outbreaks confirmed	Year	Number of outbreaks confirmed
1928	1,472	1939	3,286
1929	2,981	1940	5,019
1930	2,408	1941	1,088
1931	2,026	1942	451
1932	1,555	1943	547
1933	1,414	1944	1,449
1934	1,833	1945	928
1935	2,049	1946	347
1936	1,873	1947	37
1937	982	1948	27
1938	951	1949	5

The remarkable drop in the number of outbreaks which occurred in the war years and immediate post-war period was attributed to the reduction in the quantity of raw pig products imported from countries in which the disease is endemic.

Legislation. The various Orders controlling Swine Fever were consolidated in the Swine Fever Order of 1938 and an Amending Order of 1940. These Orders contain provisions for the notification of the suspected existence of the disease to a police constable, define the duties of the police constable, give rules for the Infected Place, for the disposal of carcases and for the disinfection and cleansing of premises, etc. The Orders also lay down that pig dealers, castrators and the owners of boars shall keep registers of their activities. They also deal with the cleansing of vehicles, crates, etc., used for the conveyance of pigs, and provision is made for placing premises believed to have held the disease or suspected pigs under movement restrictions.

The Regulation of Movement of Swine Orders of 1950 contain conditions for the prevention of the spread of the disease by restriction on sales, etc. (see above).

Procedure in the case of Suspected Swine Fever. If an owner of pigs suspects that the disease exists on his premises, he must notify the police. A veterinary surgeon encountering a suspected case in the course of his practice must take similar action. The police telegraph the information to the Ministry's head office, notify the Divisional Veterinary Officer and also an Inspector of the Local Authority. On receiving such notice the Inspector of the Local Authority serves a form on the occupier of the premises which thereby become an Infected Place. Movement of pigs into or out of the Infected Place is prohibited except under licence. Carcases and foodstuffs must not be removed and anyone having legitimate business on the premises (*e.g.*, a veterinary surgeon) must disinfect his boots, etc. on leaving. For full details of the Rules which apply on an Infected Place the Order should be consulted.

The Ministry's Veterinary Officer conducts an enquiry and if after making a post-mortem examination he suspects the presence of the disease he forwards viscera to the Ministry's laboratory for confirmatory diagnosis and advises the owner as to the steps he should take.

No compensation is paid in respect of the disease, except for such animals as it is necessary to slaughter for diagnostic purposes, the animals being valued before they are slaughtered.

The owner of the pigs has to consider what action he should take in

order to reduce his losses as much as possible. He may proceed as follows :—He may adopt a passive attitude, trusting that the disease will die out, in which case it is advisable for him to slaughter all obviously diseased animals, since these very rarely recover, and those that do are unprofitable, as they seldom thrive afterwards. He may decide to slaughter the whole of his stock, in which case he may get a licence from the Ministry, which will be granted at the time of the Veterinary Officer's visit, and later, on request, granting him permission to remove, under certain restrictions, healthy pigs to a slaughter-house or bacon factory for immediate slaughter ; or should the Local Authority give their consent, which they invariably do, he may have all the animals slaughtered and those suitable for food dressed on the premises. Provided that the dressed carcases are passed as being fit for food, these may be removed.

His other alternative is to employ his own veterinary surgeon to treat non-infected pigs with serum. This he must do at his own expense. The serum confers a passive immunity lasting approximately ten days, and during this time it is therefore necessary to mix the treated pigs with animals which have the disease in order that the passive immunity may be converted into an active immunity. If there is any doubt about the animals having been brought into contact with the disease after having received the serum, a second dose of serum should be administered ten days after the first. The serum has no curative effect, and is useless on infected animals. Its use is contra-indicated when the disease is of a particularly virulent type or is widespread through the piggery.

Serum treatment may be worth trying, either in the case of a valuable breeding herd where it is desired to save some of the foundation stock, or where the majority of pigs are not affected and there is a large number of apparently healthy store pigs which could be fattened. In many instances serum treatment in breeding establishments has given most disappointing results ; notwithstanding that the young pigs have been treated before and after weaning, the disease has broken out again and again shortly after the animals have been weaned. Thus, in some cases where serum treatment has been adopted, the disease has persisted on the premises for months or even years. Serum has given excellent results in cases where the Ministry has granted permission for the admission of store pigs for fattening, the animals receiving a dose of the serum immediately on their arrival at the premises and then being mixed with diseased animals.

The owner of the herd should consider carefully which procedure he should adopt, and during his deliberations he should attach due weight to the advice of the veterinary officer and of his veterinary

surgeon. It is probable that in most cases the most economical procedure will be to slaughter everything on the premises.

Prevention. For the effective control of this disease, it is essential that the provisions of the Swine Fever Orders should be scrupulously carried out. Early reporting of the suspected existence of the disease is imperative in order that the movement of infected pigs may be prevented as soon as possible. Pig-breeders should breed and feed their own stock as far as possible, and avoid purchasing "store" pigs through dealers. All new purchases should be kept in strict isolation for a month. When swine fever appears in a district owners of pigs should abstain from attending markets and should close their premises to visitors. Crystal violet vaccine has proved in field trials to be an effective agent in provoking an immunity which lasts for at least ten months and, when used under suitable conditions, is a useful agent in the control of the disease. Vaccination is only of value in a healthy herd ; if it is used on sick pigs and particularly pigs incubating swine fever, whether they show clinical signs or not, it is very likely to have fatal results.

PARASITIC MANGE OF HORSES, ASSES AND MULES.

Two types of mange in horses are notifiable, viz., *Sarcoptic Mange* and *Psoroptic Mange.* Sarcoptic mange which is caused by a burrowing mite, *Sarcoptes scabiei var. equi*, is the type more frequently met with in Great Britain. Sarcoptic mange generally starts on the head, neck and shoulders, but spreads over the whole body if neglected. Psoroptic mange, caused by a sucking mite, *Psoroptes communis var. equi*, is less frequently encountered. Psoroptic mange *is* the more contagious type. The disease usually starts on those parts of the body covered thickly by hair, but in advanced cases the whole surface of the body may be affected.

The sarcoptic mites penetrate the upper layer of skin and form burrows in which the eggs are laid. Each female lays from 10 to 25 eggs, which hatch in from 3 to 10 days ; the young mites after passing through several moults begin laying eggs when they are 10-12 days old. The average period of incubation (from time eggs are laid until they hatch) is about 4 days, and the average period from hatching until egg-laying begins is about 11 days. A new generation of mites, therefore, may be produced in about 15 days.

The psoroptic mites live in colonies on the surface of the skin. Each female may deposit up to 24 eggs, which hatch on the animal in

4 to 7 days The new generation of mites reach maturity and the females deposit eggs in from 10 to 12 days from the time of hatching These stages in the life cycle have an important bearing on the interval between treatments

Resistance of Mange Mites. According to Hertwig,[*] mange mites die in a few days if placed exposed in a room, probably on account of the lack of moisture If kept moist on the skin, they may live for three weeks or more, but in a dry atmosphere they die in fourteen days Brandl and Greimer conclude that the optimum temperature for mange mites is from 59° F to 86° F and that at 97°F they become dry and shrivel In warm water, according to these investigators, the mites live for twelve to fourteen days and in cold water from nine to twelve days Testing the action of certain chemicals on the mites, the above workers found that chloroform, bisulphide of carbon, and glacial acetic acid immediately kill them *Liq cresolis saponatus* and carbolic acid in 2 per cent watery solution kill in from two to three minutes A one per cent bichloride solution takes half an hour and a 20 per cent decoction of tobacco leaves did not destroy the mites in three hours Arsenious acid in a 0 5 to 1 5 per cent solution did not kill mites exposed to its action for twenty hours Mange parasites have been credited with the power to lie dormant in crevices in the stall divisions for an almost indefinite period, and to this have been attributed recurrent outbreaks of disease in stables It is more probable that the horses have never been properly cured and that a few parasites remain more or less quiescent on the skin to resume activity when conditions become favourable Nevertheless, it would be the height of folly to rely upon natural disinfection to rid a stable of the nuisance ; vigorous disinfection should be employed

Incidence. In Great Britain the first Mange Order came into force in 1912, and the returns for that year show that there were 2,873 outbreaks with 6,608 animals attacked In 1913 the number of animals attacked was reduced to 4,467 In 1916 there were 2,147 outbreaks, affecting 4 689 animals, and in 1917, 2,614 outbreaks, with 4 873 animals In 1918 the disease increased to such an extent that the official returns show 4,483 outbreaks involving 8,422 animals In 1919 there were 5 003 outbreaks with 9,773 animals attacked , since that year, however, there has been a gradual decline in the number of outbreaks until to-day the disease is practically eradicated Only one outbreak was confirmed in 1947 and one in 1948, and in 1949 and 1950 the disease did not appear in Great Britain

* *Deutsche tierarztl. Wochenschr,* XXIV , p 194 through *Vet Rev,* I , p 86.

Control and Prevention. Parasitic mange or sarcoptic and psoroptic mange of the horse, ass and mule is a notifiable disease under the Diseases of Animals Acts. When a case is suspected, provisions for dealing with it are found in the Parasitic Mange Order of 1938. Suspected cases must be isolated, and reported to the police, who inform the Local Authority and the Divisional Veterinary Officer of the Ministry whose duty it is to cause a veterinary inquiry to be made. The Local Authority shall immediately on receiving notice of disease serve a restriction notice (Form A) on the occupier of the stable, shed, field, etc., where the suspected animal is kept. If the Veterinary Officer suspects mange to exist he must send material to the Laboratory of the Ministry at Weybridge for confirmation or otherwise. On service of this notice the affected horse must be treated with a dressing, approved by the V.O., as often as is considered necessary. The affected horse or horses must not be moved out of the premises except with permission in writing by the V.O. Other horses (if not affected) may be moved out of the premises only if they have been treated all over with a parasitic mange dressing within seven days preceding date of movement. The Inspector of the Local Authority has power to have the place in which an affected horse has been stabled cleansed and disinfected at the expense of the occupier. The place, stall, etc., must be swept, and sweepings, etc., burned and mixed with quicklime and removed from contact with horses. The floor and all parts which have been in contact with the horse must be soaked or washed with an approved disinfectant, and finally the whole place must be washed, scrubbed or scoured with water. Mangers, troughs, harness, clothing, etc., must be thoroughly cleansed and then disinfected with an approved disinfectant. The detention notice (Form A) remains in force until the V. O. is satisfied that the animals are cured. When so satisfied he must inform the Local Authority who withdraw the restrictions by means of a further form (Form C).

Where the Veterinary Officer considers that any other horse, ass or mule has been in contact with the diseased animal or has been exposed to infection, he may serve restrictions on such animal or animals. This notice permits the animals to be worked provided they have been dressed within the preceding seven days.

Prevention. Despite all precautions, mange may find its way into a stable, but as a rule its appearance is due to carelessness. Most commonly its introduction is due to the purchase of a slightly infected animal ; therefore care should be taken to examine intended purchases for any suspicious signs of disease. Itchiness of the skin may, of course, be due to other causes than mange, such as lice, dirt, or to the

presence of certain forage acari. If no mange acari are found and there is no other obvious cause for the skin irritability, the animal should be treated as a suspect and isolated. Once mange has been found in a stud, the greatest care must be taken to prevent its spread from one animal to another. If the stable management is good and the horses are carefully attended to, mange should be detected very soon after its introduction, but it is astonishingly true that in a great many instances the disease has obtained a good hold before the stable foreman thinks fit to take any action. If it is not the ordinary stable practice to provide each horseman with his own set of grooming tools, this should be done immediately the disease is suspected, and all such kit must be kept clean and frequently washed in an alkali solution to remove the grease and dirt.

In some stables it is the practice to spread the least soiled bedding out in the open in the morning and then to re-apportion it to the stalls when dry. If mange is present this must on no account be allowed, even among the clean horses. The harness of all the animals, whether diseased, in-contacts or clean, should be periodically cleaned, dried in the air and dressed with some harness composition. The use of rugs, bandages and other clothing should be restricted as far as possible and, of course, under no circumstance should any harness be transferred from one animal to another.

GLANDERS

Glanders or farcy is an infectious disease due to a specific micro-organism, *Pfeifferella mallei*. It is essentially a disease of equines, and its existence is maintained by propagation in this species. Man is susceptible. The other domesticated animals are for all practical purposes immune. In the horse the disease is as a rule of a chronic type ; in the ass and mule it is generally much more acute.

Incidence. In 1906 there were 1,066 outbreaks of glanders in Britain. Ten years later the number had been reduced to 55, and in 1921, when the first edition of this book was published, the author stated it seemed probable that in the course of a few years one might expect the disease to be of rare occurrence, if not actually eradicated. That this optimistic view was justified is shown by the fact that in 1926 only one horse was found to be diseased. In 1907 there were 854 outbreaks, with 1,921 animals affected. It was in 1907 that the Glanders Order, which gave official recognition to the use of mallein for diagnostic purposes, came into force. This Order gave a decided impetus to the early detection of non-clinical or latent glanders and marked the beginning of the campaign for the total eradication of the disease from

Britain. The success of that campaign is shown by the figures in the table below which are quoted from the annual reports of the C.V.O., Ministry of Agriculture and Fisheries.

Though no case of glanders was detected in 1927, one horse was found at Southampton to be clinically affected in 1928 and gave a positive reaction to the mallein test. It was slaughtered, but no material was submitted to the Ministry's laboratory for confirmatory diagnosis. The clinical history and post-mortem findings, however, left little room for doubt as to the animal's condition. This is the last case recorded in Great Britain.

Incidence of Glanders in Great Britain.

Year	Outbreaks	Horses attacked
1907	854	1,921
1908	789	2,433
1909	533	1,753
1910	351	1,014
1911	209	504
1912	172	315
1913	162	438
1914	97	286
1915	49	85
1916	46	117
1917	25	63
1918	34	98
1919	25	61
1920	15	25
1921	11	45
1922	4	4
1923	9*	16
1924	3	4
1925	2	2
1926	1	1
1927	0	0
1928	1	1

* Six of the outbreaks in 1923 occurred in imported animals.

Legislation. The Order dealing with glanders is the Glanders or Farcy Order of 1938. Notification requires to be made to a police constable, who must *immediately* notify the Divisional Veterinary Officer of the Ministry and an Inspector of the Local Authority. The latter must inform the Local Authority and the Medical Officer of Health of the district. The Veterinary Officer is bound to make an *inquiry* and report his findings to the Ministry and to the Local Authority. If they think fit, the L.A. may give public *warning* of the existence of the disease by the use of placards or otherwise. Diseased, suspected

animals and "in-contacts" must be detained in isolation   Diseased animals must be slaughtered and compensation paid to the owner   The V O must apply the mallein test to any animal detained under Art 6 of the Order, other than a diseased animal   Reacting animals must be slaughtered   A post mortem examination must be held on every animal slaughtered, and if the V O finds evidence of the disease necessary material for diagnostic purposes must be sent to the Ministry   Prohibition of movement of diseased or suspected carcases and of dung, litter, etc, is enforced   The Crown is not bound by this Order (this means that animals belonging to the Crown e g, army horses, etc, may be exempt from the conditions of the Order)

Prevention. Protection against the introduction of glanders with imported horses is given by the Importation of Horses, Asses and Mules (Great Britain) Order, 1938   By this Order horses, with certain exceptions, may be landed in this country only if accompanied by a certificate of a duly authorised Veterinary Officer of the district of origin stating that the animal is free from disease and has passed the mallein test within ten days previously   Horses from Ireland, Channel Islands and the Isle of Man are exempt from this Order   Horses may be landed from Iceland and the Faroe Islands without having been subjected to the mallein test provided they are certified as being free from disease

Protection against the introduction of glanders into coal mines is provided by Part I, Third Schedule of the Coal Mines Act, 1911 No horse shall be taken underground until it is four years old and until it has been tested by a veterinary surgeon in the prescribed manner and certified to be free from glanders

SHEEP SCAB

Sheep scab has been known and recognised for a very long time It was known to Moses (Leviticus xxii 22) but it was not until 1809 that the causal mite or acarus was discovered by Walz.

Sheep scab, i e, psoroptic mange of sheep, is caused by a mite, *Psoroptes communis var ovis*   This is a sucking mite, and derives its nourishment while living on the skin by puncturing the latter and sucking fluids   The parts of the animal usually attacked are the shoulder, rump and tail, but in bad cases the disease may spread over the entire body   The acarus when adult measures 1/40th to 1/50th of an inch in length.   The male is smaller than the female, but both can just be seen with the naked eye

Two other forms of sheep scab occur, caused by *Sarcoptes scabiei var ovis*, and *Chorioptes ovis*   The sarco——

head and ears and sometimes on the tail, while the chorioptic variety confines itself to the limbs and the base of the tail. Both these forms of scab are comparatively uncommon, the usual form being the psoroptic variety, which gives rise to much more severe symptoms, with greater tendency to spread rapidly through a flock. Only two forms of scab are notifiable under the Diseases of Animals Acts, the psoroptic and sarcoptic.

The life-cycle of *Psoroptes communis* is briefly as follows :—The female lays eggs which hatch out into hexapod larvae in about four days. Stockman found that eggs which did not hatch before the eighth day did not produce larvae. The larvae feed, moult and become nymphae in two to three days ; the nymphae moult and become adult males and females in another three to four days. Another two to three days may be allowed for mating and egg laying, thus completing the life history from egg to egg in about 14 days. This is a very important point which must be taken into consideration in the treat-ment of the disease. It is known that one dipping will destroy the acari, but no dip can be relied upon to destroy the eggs. Using a dip which has no prolonged residual effect, the first dipping will destroy the acari only ; a second dipping is therefore necessary and it must be done late enough to ensure that all the eggs of the old brood have hatched out, and early enough to destroy the new brood of acari. From the above data it will be seen that most of the eggs hatch in 3 to 4 days but that some may take 8 days. It will also be observed that the new brood of acari begin to lay eggs about the fourteenth day, so that the second dipping must be done between the eighth and fourteenth day, during which period only acari are present and will therefore be destroy-ed. Dips containing the gamma isomer of benzene hexachloride, however, have a residual effect extending over this period and so when these dips are used there is no necessity for a second dipping.

Survival of Acari. It is often believed by stockowners and others that the acarus of scab can survive for long periods on gates, posts, etc., and thus cause re-infection of flocks. Stockman showed by experiments that acari do not survive on heavily infected wool for longer than 31 days, and that in infected wool kept for 15 days and over the majority of the acari are dead. He also attempted to infect sheep with heavily infected material which had been kept for a month, but all the attempts failed. The same experimentist placed sheep in pens which had held sheep badly affected with scab and which had been vacated for different periods ; positive results were obtained in pens left vacant up to 8 days, while in pens left vacant for 14 days the sheep which were put in remained healthy. Stockman stated : "It is clear from these observa-

tions that persistence of scab on sheep farms and recurrences of disease after intervals of weeks or months are not due to the survival of the parasites or their eggs off the sheep, attached to posts, fences, etc., or on the ground, and that they leave no other conclusion possible except that infection, when it persists, does so on the sheep. This is a most important practical observation with regard to eradication of scab in flocks ; it shows that, with proper treatment of the sheep, the disease can be eradicated. It is in the winter months that the disease is seen in the actively progressive form with rapid spread of the characteristic lesions. During the summer the sheep may be apparently free from infection but it is now known that the mites survive in protected sites on the animal's body, e.g., in the infra-orbital fossae, on the scrotum, or in the original folds. The disease thus remains latent, the rate of oviposition being markedly slowed and the colonies just surviving without multiplication until the cold weather comes and the disease flares up again. Sometimes, however, a slow progressive form of the disease is seen during the summer months with, again, increased activity in the autumn.

Incidence. Sheep scab is known in practically every country in the world. In Great Britain regulations have been in force for a considerable number of years, with a view to reducing the incidence of the disease, if not totally eradicating it. From the following table, taken from the C.V.O.'s reports, it will be seen that considerable progress has been made in this direction :—

Number of Outbreaks of Sheep Scab, 1922-1949

Year	No. of Outbreaks	Year	No. of Outbreaks
1922	683	1936	255
1923	690	1937	253
1924	575	1938	222
1925	670	1939	276
1926	717	1940	228
1927	723	1941	255
1928	744	1942	283
1929	666	1943	257
1930	478	1944	245
1931	347	1945	121
1932	361	1946	94
1933	578	1947	103
1934	684	1948	69
1935	477	1949	46

The disease has not occurred in Scotland since 1941 and in England outbreaks are now confined to the moorland and mountain areas of the Pennine Chain. In Wales nearly all recent outbreaks have been

in the Berwyn Mountains on the borders of Merioneth, Montgomery and Denbigh and the Black Mountains of Brecon and Monmouth.

The main obstacle to the complete eradication of the disease is the existence of common unfenced grazings in these areas. Wherever such grazings exist there is always the danger that gatherings for dipping may not be complete and thus some infested sheep may escape detection and treatment and thus provide a focus for further outbreaks. If the full co-operation of flockmasters can be obtained in ensuring that all sheep on such grazings are dipped without exception then there is no reason why the disease should not be eradicated. Intensive action is now being taken by the Ministry to eliminate sheep scab from these few remaining infected areas using benzene hexachloride dips which, after a single dipping, give several weeks' protection from re-infestation.

Prevention. Sheep scab spreads through a flock by direct contact of one animal with another, and indirectly from contact with contaminated rubbing posts, tree trunks, rocks, gates, etc. *The disease is disseminated by movement of sheep from infected farms to other farms, either directly or through dealers or markets.* It has already been noted that sheep may be harbouring infection and yet not show clinical signs of disease, and herein lies a great difficulty in eradication.

The careful flock-master's best preventive against sheep scab is the regular periodic proper dipping of his flock. Where fresh sheep are brought on to the farm, they should be dipped in an approved benzene hexachloride dip before they are mixed with the flock.

Portal inspection and dipping at the landing place of sheep shipped from Ireland checks the introduction of disease into this country.

Legislation. Sheep scab is a notifiable disease under the Diseases of Animals Acts. Provisions for dealing with it are laid down in the Sheep Scab Order of 1938. Every owner or person in charge who suspects the disease must notify a police constable who must immediately pass on the information to the Divisional Veterinary Officer of the Ministry and to an Inspector of the Local Authority. The latter must serve a Form placing the premises under restrictions prohibiting the movement of sheep either out of or into such premises. The Veterinary Officer must arrange for a veterinary examination of the suspected sheep and report to the Local Authority and to the Ministry. Should he suspect scab to exist he must send material (usually mounted acari if possible) to the Laboratory of the Ministry at Weybridge.

If scab is confirmed by the C.V.O. the V.O. serves a notice on the owner to double-dip his affected and his contact sheep and also gives advice regarding the hand dressing of those actually affected.

The affected flock must remain in isolation until the V.O. considers all the sheep are free from the disease.

The Sheep Scab Order gives the Local Authority power to slaughter ownerless sheep which come within the scope of the Order. (For Dips and Dipping see pp. 328f.)

Where in any particular district sheep scab is known to be prevalent, the Ministry has power to declare such an area to be a "Double Dipping Area" or a "Movement Area." In a "Double Dipping Area" all sheep within it must be double dipped (i.e., dipped twice, the second dipping to take place not earlier than the eighth day, nor later than the fourteenth day, after the first dipping) within a specified period. In a "Movement Area" sheep may not be moved out of such area except under licence, and then only if they have been double dipped before being moved.

Under the Sheep Scab (Amendment) Order of 1948 single dipping with an approved benzene hexachloride dip is authorised as an alternative to double dipping with one of the older types of approved dip. Provided that an approved benzene hexachloride dip is used, the second dipping between the eighth and fourteenth day is not called for.

SHEEP-POX

Sheep-pox (variola ovina) does not at present exist in Great Britain. It was imported into this country in 1847 from Denmark but was stamped out after four years. It reappeared in 1862, but more vigorous measures were adopted for its control and after four months it was completely eradicated and has not appeared since. At present sheep-pox has been controlled or eliminated from the greater part of Europe. It continues to exist in Southern and Eastern Europe and in North Africa. The controlling Order in Great Britain is the Sheep-Pox Order of 1938. Suspected cases must be notified to the police.

RABIES

Rabies (hydrophobia, lyssa) is a disease to which all warm-blooded animals, including man, are susceptible, but it is essentially a disease of canines and is propagated chiefly by them. The infective agent is present in the saliva, and as rabid animals of nearly all species develop a marked tendency to bite, transmission in natural cases occurs in this way. Even animals which are naturally docile, e.g., sheep, become very aggressive when attacked by the disease. An interesting outbreak occurred in 1887 among the deer in Richmond Park and this same tendency was noted.

In rabid animals the virus is present in the brain and spinal cord, the peripheral nerves, the salivary glands and the saliva. It has been demonstrated in the saliva of dogs 4 days before symptoms developed.

The period of incubation in man and animals is variable ; it is generally about 1 to 3 months, and is rarely shorter than 15 days or longer than 6 months. During the interval between infection and the appearance of the symptoms the virus is travelling up the peripheral nerves and spinal cord to the cerebrum, and the incubation period depends on the distance to be travelled. Thus, symptoms appear more rapidly after bites on the face than after bites on the leg. Once symptoms develop, the disease is almost invariably fatal, and generally lasts from four to seven days. Symptoms, however, do not always appear in a person or animal that has been subjected to infection.

In considering the risk of infection, it should be noted that it has been found experimentally that different strains of rabies virus vary considerably in their pathogenicity for animals, some strains rarely producing infection when injected subcutaneously, while others invariably do so. Rabies, too, is more likely to develop after bites on an area with a rich nerve supply, *e.g.*, the face, as there is then more likelihood of the virus coming in contact with the torn ends of nerves.

If a person has been bitten by a dog about whose condition there is doubt, it is essential to find out whether the animal is suffering from rabies, and the diagnosis can only be effected in a laboratory. The dog should be destroyed, but not by shooting, and the head should be removed, packed in ice and forwarded without delay. If ice is not available, the head should be wrapped in a cloth soaked in glycerol in order to hinder bacterial multiplication.

If the dog is thought to have been affected, treatment of the person bitten should be sought as soon as possible.

Incidence. Rabies was at one time quite common in Britain, and from time to time muzzling orders were enforced over infected areas, but it was clear that if the disease was to be eradicated its importation from other countries had to be prevented, and in 1897 regulations were issued requiring that all imported dogs had to be kept in quarantine. These regulations were revised in 1901, and during 1902 the disease was eradicated, and the country remained free from the disease until 1918. During that year it was reintroduced, it is assumed, but not definitely known, by a dog which came over from the Continent with returning troops. The disease spread very rapidly through the south of England and South Wales, and in the official report of the C.V.O. of the Ministry of Agriculture and Fisheries, 1921, it is stated that 319 dogs were affected and that 358 persons were known to be bitten by diseased

or suspected dogs It took four years to stamp the disease out Britain has been entirely free from rabies since 1922 except for a few cases occurring in quarantine This fortunate position is due to the rigid enforcement of the quarantine regulations and to the careful control of the animals kept in quarantine The occurrence of the disease in quarantined animals emphasizes the need for continued watchfulness

Legislation. There are two Orders dealing with rabies and with the importation of animals which might introduce disease These are the Rabies Order of 1938 and the Importation of Dogs and Cats Order, 1928

Rabies Order of 1938—Notification of the suspected existence of disease is to be made by the owner or person in charge to a police constable who must immediately inform the Divisional Veterinary Officer and an Inspector of the Local Authority

The L A must slaughter every dog and cat within their district which is diseased or suspected, or which is known to have been bitten by a diseased dog or cat

The V O has to inquire into the suspected cases, to report to the Ministry, to make a post mortem examination, and to forward the necessary diagnostic material to the Ministry

All dogs and cats which have been exposed to the infection or any other animal which is diseased or suspected, or which has been exposed to the infection of rabies, must be detained in isolation.

Importation of Dogs and Cats Order, 1928—Previous to 1928, the Importation of Dogs Order for 1914 and amending Orders required that all imported dogs should be kept in quarantine for a period of six months, but owing to the frequency with which cats were found to be affected with rabies on the Continent of Europe, the Ministry made a new Order, the Importation of Dogs and Cats Order of 1928, which states that no canine or feline animal can be brought to Great Britain from any other country except Ireland, the Channel Islands and the Isle of Man, unless a licence has been granted for its landing and that it is kept in quarantine upon approved premises for a period of six months *Bona fide* performing animals, canine animals other than the domestic dog or feline animals other than the domestic cat which are imported for breeding, or exhibition or other special purposes may be landed subject to certain conditions

Regulations applying to Dogs and Cats in Quarantine—Each animal has to be kept in a separate kennel and exercised only in a confined yard from which it cannot escape nor come into contact with other animals Not more than one dog or cat may be kept in a kennel The mating of dogs during quarantine is prohibited, as also is the

artificial insemination of bitches.   Quarantine kennels have to be under the direct control of a veterinary surgeon.   Objections are raised from time to time by owners of dogs, or persons desirous of importing dogs, to the lengthy period of quarantine.   The Ministry has clearly shown that owing to the prolonged incubation period of rabies, six months is the shortest period of detention that can, with safety, be allowed.   In 1947 a dog had been under quarantine conditions for eight months before it showed symptoms of the disease.   It should be fully realised that the quarantine restrictions must be stringent if the reappearance in this country of this horrible disease is to be prevented, for, as mentioned above, a number of cases have occurred in quarantined animals in recent years.

EPIZOOTIC LYMPHANGITIS

Epizootic lymphangitis is due to a specific yeast-like fungus, *Cryptococcus farciminosus*, and is characterised by lesions which bear a strong resemblance to those of farcy.   The disease is strictly contagious and is confined to equines.   Epizootic lymphangitis, which was first described by Rivolta in 1873 in Italy, was introduced into Great Britain by army horses after the South African War (1902), but was stamped out by 1907.   Since that date the disease has not recurred here. Infection occurs by inoculation of the organism through the skin, and though cutaneous injuries such as abrasions favour entry of the organism infection can apparently occur through sound skin.   Spread from diseased to healthy horses is largely brought about by the indiscriminate use of grooming tools and harness, the organism being present in the pus from the lesions.   Many observers regard flies as being important agents in the spread of the disease.   The existence of the infection is largely maintained by the insidious nature of the malady. The period of incubation is as a rule very prolonged, *e.g.*, Perrin* noted that in 5 cases the average period was 118 days, and Drouin believes that it is never less than three months.   It is thus easily understood how new centres are established by the sale of apparently healthy, but in reality infected, animals.   The disease is not as a rule fatal ; the duration in untreated animals is very long.   Cases are generally slowly progressive, and tend to recur after apparent recovery.   The cryptococcus is very resistant to destructive agencies, and especially to chemical disinfectants.   There is reason to believe that discharges in a stable may maintain their virulence for at least a month. †

* *Trop. Vet. Bull.*, 1917, 5, p. 183.
† Report, C.V.O., Bd. of Agric., 1905.

Preventive Measures. Any animals affected with the disease would be destroyed ; under Sec. 17 of the 1950 Act, the M. of A. has power to make an Order for this purpose. Prevention of this disease calls for the exercise of prolonged vigilance owing to the long incubation period, the resistance of the organism to ordinary antiseptics and to the tendency of the disease to recur. After the destruction of infected animals a very close watch upon contacts is necessary. The stud cannot be declared free until six months after the infected animals have been destroyed. Great care must be exercised in disinfecting grooming tools, clothing, etc., before they are re-used. Heat should be the disinfecting agent used, since the organism is so resistant to disinfectants of a chemical nature. Sponges must not be used, and in hospitals it is important to forbid the indiscriminate use of swabs and antiseptic fluids ; all such should be discarded after first use.

Legislation. The disease is controlled by the Epizootic Lymphangitis Order of 1938.

CATTLE PLAGUE : (RINDERPEST)

Cattle plague, or rinderpest, is an acute febrile disease of ruminants caused by a filterable virus, and characterized by a rapid course and a high mortality rate. The chief lesions are found in the intestinal tract. The disease is indigenous in certain parts of Asia, and causes considerable ravages in Africa. It has been responsible for outbreaks in this country, but the last occurred in 1877. It was eradicated from the United Kingdom by the method of slaughtering out, and should the disease at any time in the future be introduced, the same methods would be adopted.

Legislation. The disease is controlled by the Cattle Plague Order and the Amending Order both of 1938.

CONTAGIOUS BOVINE PLEURO-PNEUMONIA

Contagious bovine pleuro-pneumonia (lung plague) is an acute or sub-acute, though frequently somewhat insidious, disease affecting only bovine animals and caused by an exceedingly minute organism which can only be seen under a magnification of about 2,000 diameters. The disease is characterised by lung lesions of a peculiar type and by a fibrinous exudative pleurisy, though the latter lesions are secondary to the pulmonary involvement and may not always be present.

Pleuro-pneumonia was at one time a very widespread disease both throughout the world and in Great Britain. It was first introduced here, it is thought from Holland, about 1840, and its very considerable ravages may be gathered from the statement that in 1873 there were 2,711 outbreaks, involving 8,817 animals ; in 1874, 3,262 outbreaks, involving 9,225 animals ; and in 1877, 2,007 outbreaks, involving 6,683 animals. During the 25 years ending 1894, 103,000 animals died or were slaughtered in the British Isles as the result of the disease.* In 1873 slaughter of diseased animals was first made compulsory, but until 1888 for certain reasons little real progress was made in the extermination of the disease. In 1888, however, the principle of compulsory slaughter of affected animals and all in-contacts was put into practice, the result being that by 1897 the disease had been stamped out of country districts and was only present in the east end of London. The disease has been non-existent in the British Isles since 1899.

The method of infection is by inhalation of infected particles contained in the expired air of diseased subjects, and transmission can thus readily take place in animals which are stalled close together. The period of incubation is somewhat lengthy and is generally considered to be about 6 weeks. A rise of temperature occurs earlier than this however, and Nocard and Roux placed the period of incubation after inhalation at 12 to 16 days. The organism of pleuro-pneumonia possesses very little resistance to drying, heat, or chemical action. The virus is kept alive in areas where the disease is endemic chiefly because it is harboured and excreted for long periods by apparently recovered animals.

Preventive Measures. Outbreaks in the British Isles would always be dealt with by slaughtering diseased and in-contact animals.

Legislation. The controlling Orders are the Pleuro-Pneumonia Order of 1928 and the Amending Order of 1938.

TUBERCULOSIS

Tuberculosis is a contagious disease of man and animals, caused by the *Mycobacterium tuberculosis*. Koch first discovered the micro-organism in 1882, although Villemin, in 1865, had demonstrated that tuberculous tissue from man and cattle produced the disease in rabbits by inoculation.

* Report, C.V.O , Bd. of Agric., 1895.

Mycobacterium tuberculosis is a slender, usually slightly bent bacillus, from 1 5 to 5 *u* long by 0 3 to 0 5 *u* broad It belongs to the so-called "acid fast" group of organisms, being covered with a thin waxy material, which gives it its acid fast character It is non-motile and non sporulating The organism is a tissue parasite, and occurs singly in the tissues, but in secretions such as milk it often occurs in pairs or in bundles, either parallel or placed together at angles In milk, and sometimes in expectorate, the organism when stained takes on the stain irregularly and appears "beaded" This is a most important characteristic, and is of a great diagnostic value in the microscopic examination of milk, and of expectorated matter It is most easily stained by the Ziehl-Neelsen method with hot carbol-fuchsin, after which the preparation is de-coloursed by acid and counter-stained by methylene blue in weak solution, the tubercle bacilli show up red amongst the blue background of cellular content

There are three recognised types of tubercle bacilli in warm blooded animals, namely, the human, the bovine and the avian These are differentiated by their behaviour on various media and their pathogenicity for certain animals It is important to realise that they cannot be differentiated by a microscopic examination alone

Amongst domestic animals cattle are the most commonly affected, but the disease is also met with to a large extent in the pig and in poultry The dog, cat horse sheep and goat are all susceptible, it is a frequent disease in the camel and to a lesser degree in the buffalo Most wild mammals are susceptible, especially in captivity

To the student of veterinary hygiene the disease in cattle is by far the most important, especially inasmuch as the bovine variety is liable to affect human beings In fact this phenomenon is the cause of the widespread public interest taken in the disease to-day and the very great importance it has assumed in regard to our milk supply The following points are noteworthy —

(a) That cattle are susceptible to a natural infection with the bovine type and to a much lesser extent with the avian

(b) That man may be infected either by the human or by the bovine strain

(c) That swine are chiefly infected with the avian and bovine types, but may also naturally contract the disease from human strains

(d) That the dog may contract tuberculosis either from bovine sources or be affected by the human type of organism from man

(e) Farmyard poultry are commonly affected with the avian strain

BOVINE TUBERCULOSIS

Tuberculosis in cattle is usually of a chronic nature and as a rule is slowly progressive. The reason for this is the natural resistance shown by cattle against the disease and the fight they can put up against its spread in the body. Nevertheless, any adverse condition to which any animal may be subjected, such as change of surroundings, sudden changes of weather, turning cattle out in spring after being housed all winter, the strain of calving, and so on, are liable to break down the natural resistance in the body so that latent lesions of the disease may rapidly become acute and death occur in a few weeks if the animal is not slaughtered. Tuberculosis is a disease of advancing age, its incidence being much lower in calves and yearlings than in older cattle. The incidence is also higher in cows than in males, chiefly due to the mode of life and the housing of dairy cows in large numbers. The percentage of cattle reacting to the tuberculin test varies greatly in different areas, being lowest on the small breeding farms where few cattle are bought in, and highest in large dairy herds, especially in the so-called "flying herds." The overall incidence of bovine tuberculosis in Great Britain is difficult to estimate but it is probable that the incidence in dairy cows of five years and over is about 40 per cent. In young animals, however, even in heavily infected herds the incidence is low, and it is probable that of all cattle in Great Britain not more than about 17 per cent. are affected with the disease.

The disease has been practically eradicated from the United States, Finland, Norway, Portugal and Denmark. The Channel Islands are free of bovine tuberculosis.

Methods of Dissemination. The period of incubation is very variable and uncertain. Months or years may elapse before any recognisable clinical signs manifest themselves, but the absence of such signs does not mean that infection has not taken place. The most common means of spread is probably by direct contact with a diseased animal, and it must be realised that an animal showing no clinical signs whatever can spread infection.

Inhalation is the commonest means by which the organism enters the body, and this is also suggested by the great frequency of lesions occurring in the lungs and/or the bronchial and mediastinal lymphatic glands. Tubercle bacilli contained in expired air and in expectorated matter, which is frequently abundant in active pulmonary cases, are the most fertile source of infection. Expectorate may also be swallowed, and thus be the means of infecting the mesenteric glands, and even

the bowel wall, and thus contaminating the faeces   Bacilli are some-
times voided with the urine, for lesions in the kidneys of cows are
very common, and in cases where the uterus is involved, in the
vaginal discharge   Thus ill ventilated and insanitary cow-sheds readily
allow healthy cattle to become infected by their neighbours   Soiled hay
and other foodstuffs may also convey disease, especially where it is
customary to store fodder in feeding passages in front of the cows or
even anywhere in the cow-shed

Infection by ingestion is, however, much less frequent though the
feeding of calves in milk from cows with tuberculosis of the udder
may have serious results, thus it is particularly important that great
care should be exercised in the choice of "nurse" cows for rearing
calves   Primary infection of the udder or uterus may occur through
the use of contaminated instruments in minor operations such as udder
injections and uterine irrigations   The need for very careful sterilis-
ation of such instruments cannot be over-emphasised

Viability.   The resistance of the tubercle bacilli is very high, and on
knowledge of this must rest methods of disinfection of premises
According to Hutyra and Marek, in dry sputum protected from light
they may remain infective for 126 days   Decomposition affects their
vitality but little, thus decomposing sputum harbours tubercle bacilli
for six weeks, and decomposed cattle dung for 167 days *   Desiccation
alone is thus not a destructive agency   Experiments carried out by
Williams and Hoy showed that under ordinary conditions the bacillus
may remain alive and virulent in cows' faeces exposed on pasture land
for at least five months in winter, two months during spring and
four months during autumn   In summer no living organisms were
demonstrated after two months   When protected from direct sunlight
the surviving period may be four months during summer   In autumn
faeces protected from earth worms showed the presence of bacilli after
six months   The same workers also showed that virulent tubercle
bacilli might be found after twelve months' storage in naturally
affected faeces and for at least two years in artificially infected faeces
It was also found that virulent tubercle bacilli might still be found in
stored liquid manure at least four months after infection, but a gradual
diminution of their virulence was taking place †   Work carried out by

*Hutyra and Marek, *Special Path and Therap of the Diseases of the Domestic
Animals*, 4th edition 1938, Vol 1, p 562.
†Williams R S and Hoy, W A (1930)   The Viability of Bacillus Tuberculosis
(Bovinus) on Pasture Land, in Stored Faeces and in Liquid Manure *J Hyg*,
Vol XXX.

Maddock* seems to prove, to use the author's words, "that in pasture which has been previously naturally infected, so long as no contact with the infecting animals is possible, healthy animals may be expected to escape infection from this source." It therefore appears that the danger of infection being picked up from pasture manured with farmyard manure is remote. The most usual method of spread of the disease is undoubtedly by inhalation.

This seems to be borne out in practice under the Attested Herds Scheme, for it is usual to allow clean cattle to be grazed on land previously grazed by non-tested stock after the land has been kept vacant for one month. The result of this procedure has not shown that any infection has taken place in the herds from this cause.

Legislation. The first attempt to deal in any way with the menace to human health from tuberculosis in cattle was made in 1899 as the result of the Report of the Royal Commission on Tuberculosis (1898), and was embodied in the Dairies, Cow-sheds and Milk Shops Order of 1899, which amended the original Order of 1885. In this amended Order power was given to prohibit the sale or use of milk from a cow affected with "such disease of the udder as was certified by a veterinary surgeon to be tubercular." Incidentally, this was the first official recognition of the veterinary profession in our milk legislation. With the exception of this Order, which was largely a "dead-letter," no further efforts were made to deal with bovine tuberculosis till 1909, when the introduction of further control was discussed, but the proposed Order was never enacted, the first legislation giving power to slaughter a diseased animal was contained in the Tuberculosis Order of 1913. This Order was the first serious step in the campaign against bovine tuberculosis, but its scope was confined to cows suffering from tuberculosis of the udder or giving tuberculous milk or to bovine animals suffering from tuberculous emaciation. The Order required the compulsory slaughter of animals so affected and allowed a graduated scale of compensation to their owners.

The 1913 Order was replaced in 1914 by another Tuberculosis Order, which, however, was withdrawn on 6th August of that year as a result of the War. The new Order included, in addition, bovines suffering from a chronic cough and showing definite clinical symptoms of tuberculosis. Nothing further was done to control the disease until the passing of the Milk and Dairies (Amendment) Act of 1922, which gave power to grant licences for the production of "Certified" and

*Maddock, E. C. G. (1936). Experiments on the infectivity for healthy calves of bovine tubercle bacilli, discharged in dung upon pastures. *J. Hyg.*, XXXVI., 594-601.

Grade "A" (Tuberculin Tested) Milk under the Milk (Special Designations) Order 1923, later amended to that of 1934 and 1936 In addition, this Act made it an offence to "expose for sale the milk of any cow suffering from tuberculosis of the udder," but no power was given to slaughter such an animal nor to insist on its removal from the herd.   Certain cities had before this date brought in local Acts of Parliament to prohibit the use of milk from animals so affected and to compel their removal from their areas   The milk and Dairies (Consolidation) Act, 1915, which was postponed owing to the War and only operated from 1st September, 1925, made it an offence "to sell the milk from any cow which has given tuberculous milk or is suffering from emaciation due to tuberculosis or from tuberculosis of the udder" (This is now embodied in the Food and Drugs Act, 1938)

At the time that this Act came into force the Tuberculosis Order of 1925 was instituted   The Order, which like its predecessors was purely a public health measure, made it obligatory for local authorities to cause to be slaughtered any cow or heifer which was suffering from tuberculosis of the udder or giving tuberculous milk or any bovine which was suffering from tuberculous emaciation or from a chronic cough and showing definite clinical signs of tuberculosis, and it was an offence for any owner not to report any such animal in his possession

The Tuberculosis Order of 1925 was later replaced by the Tuberculosis Order of 1938   The new Order was essentially the same as its predecessor but was altered chiefly owing to the Ministry of Agriculture having taken over the purely veterinary duties from local authorities   Power to slaughter affected cattle was transferred to the Ministry and the compensation to owners for slaughtered cattle is now paid by the State instead of by the local authority   As in the earlier Order, a scale of compensation is paid to the owners, dependent on the market value of the animal at the time of slaughter (which value must be agreed on first) and the extent of the disease as disclosed by a post mortem examination   Under the Tuberculosis (Amendment) Order of 1946 any bovine animal which is excreting or discharging tuberculous material is also regarded as an affected animal

Any veterinary surgeon who in the course of his practice is employed to examine any bovine animal and who is of the opinion that it is an affected animal for the purposes of the Order must report the case to a police constable or to a Veterinary Officer of the Ministry of Agriculture Likewise the owner of any suspected animal must report it either to a Veterinary Inspector or to a police constable   On receiving such information the police constable must immediately report the matter to the Divisional Veterinary Officer whose duty it is to arrange for an examination of the suspected animal   Should the animal in the

opinion of the Veterinary Officer be amenable to the Order the valuation must be agreed upon between the owner and the Veterinary Officer as representing the Ministry. Should agreement not be reached, provision exists for calling in a valuer. When the valuation form is signed the slaughter is proceeded with as soon as practicable. Where cattle which are suspected of falling within the scope of the Order are detected on routine clinical examination of dairy cattle, the Veterinary Officer deals with the case in the usual way. Power exists for the Veterinary Officer to insist on a thorough disinfection of the stall or box occupied by the diseased animal, and a copy of any such disinfection notice must be sent to the local authority who may supervise the disinfection by one of its officers.

The Tuberculosis Order has been much criticised by some on the grounds that only animals in the last stage of the disease are reported, but, while this may be true, in many cases since the system of routine clinical examination of dairy cows has been instituted the Order has been of value. Numerous cows in the early clinical stage of the disease are detected by this means, and by submitting samples of milk from any suspicious or abnormal udder to a microscopic examination many positive results can be obtained. The microscopic examination of expectorate is also instrumental in bringing many cases of pulmonary disease to light. Tuberculosis of the udder cannot be diagnosed by a clinical examination alone, although it may be strongly suspected ; the only certain method is the finding of one or more acid-fast organisms at microscopic examination, or by means of a biological test. The finding of the so-called cell groups as described by Torrance and others is of great help in arriving at a diagnosis, although they must not be considered as pathognomonic.

The number of animals slaughtered under the Order in recent years is shown in the following table, the figures being taken from the Reports of Proceedings under the Diseases of Animals Acts :—

Cattle slaughtered				Cattle slaughtered			
1938	...	...	...	19,910	1944	...	...	...	11,747
1939	...	...	...	17,686	1945	...	...	...	9,633
1940	...	...	...	15,501	1946	...	...	...	8,266
1941	...	...	...	14,212	1947	...	...	...	6,545
1942	...	...	...	13,480	1948	...	...	...	6,320
1943	...	...	...	14,360					

The following comment on the trend of these figures appears in the Report for the years 1938 to 1947 :—

"The substantial decline in the number of cattle slaughtered cannot be taken as a measure of a general decline of the incidence of bovine tuberculosis. During the war years, dairy farmers were

encouraged to cull unhealthy and unthrifty animals and many such animals affected with tuberculosis in a sub-clinical form were culled before developing clinical symptoms of the disease. This is the most probable explanation of the progressive and very substantial reduction of emaciation cases dealt with under the Order.

On the other hand, the decline in the number of cattle slaughtered has been most marked in districts in which the Tuberculosis (Attested Herds) Scheme has made good progress, and it is safe to say that in those districts there has been a reduction of the incidence of tuber-culosis."

Milk legislation. As already mentioned the Milk and Dairies (Consolidation) Act, 1915 which came into operation in 1925 made it an offence to sell milk from any cow "which has given tuberculous milk or is suffering from emaciation due to tuberculosis or from tuber-culosis of the udder." This Act has now been superseded by the Food and Drugs Act, 1938, which contains a clause similar to the above.

Tuberculin Tested Milk, that is milk from cows which have passed the tuberculin test, was first officially recognised in 1923 when the first licences were granted, under the Milk (Special Designation) Order, 1923, for the production of Certified and Grade A (Tuberculin Tested) Milk the former being bottled on the farm and the latter sent off the farm in bulk. Under the Milk (Special Designations) (Raw Milk) Regulations 1949, licences authorising the use of the designation Tuberculin Tested Milk are now granted, these regulations having replaced all the earlier Milk Special Designations Orders. After 1st October, 1957 the special designation "Tuberculin Tested" will only be allowed in respect of milk from a herd which is on the Register of Attested Herds and after 30th September, 1954 new licences to use that designation will only be issued where the herd is already registered as an Attested Herd.

Eradication. The earliest schemes aiming at eradication are associated with the names of Bang and Ostertag. Bang's method consists in the destruction of all clinically affected cattle and the separation of reactors from non-reactors, as revealed by the use of the tuberculin test. The herd is placed in two separate sets of buildings and pastures with separate attendants for each. The reacting herd is frequently examined, and any animal showing clinical signs is at once destroyed. Calves from reactors are removed at birth and reared away from infection on tubercle-free milk or milk which has been properly pasteurised. Tuberculin testing must be regularly carried out on the free portion of the herd, and also on the young stock after weaning. Any of the latter which react to the test must be at once disposed of. The method

has been very successful in countries where it has been practised, and provided reasonable care is exercised, a tubercle-free herd can be formed in a few years. Ostertag relied upon the removal of all clinically affected cows, and only utilised the tuberculin test for the young stock. The calves were fed on milk sterilized at 85° C. He laid great stress on the removal of the clinical cases at the earliest opportunity, and recommended periodical testing of the mixed milk of the herd for tubercle bacilli. This method could not prove effective as the removal of "open" cases alone can never eliminate tuberculosis from the herd.

In the United States of America and in Canada the use of tuberculin and the slaughter of reactors, along with the formation of "accredited" or tubercle-free herds, and thereafter the clearing out of the disease from large areas, known as "accredited areas," have so reduced the incidence of bovine tuberculosis that it is now rapidly reaching the vanishing point. Unfortunately in Great Britain the problem is much more complicated and it was not until 1935 that any official steps were taken towards eradication, when the Attested Herds Scheme was first instituted. Previous to this the Milk (Special Designations) Orders, as already stated, had not been sufficiently made use of, but it had been shown that in this country isolated herds could be freed from tuberculosis by means of the tuberculin test with the isolation and ultimate removal of all reactors. This must be carried out along with strict and thorough disinfection of premises where infected cattle have been kept. Probably the first step to eradicate tuberculosis from a group of farms in this country was made in Ayrshire under the auspices of the Medical Research Council, and in view of the Attested Herds Scheme it is interesting to describe this first venture.

In this case the experiment was carried out under ordinary farm conditions and with no further inducements offered to the farmers than free tuberculintesting and free advice as regards the rearing and management of their stock. An area of about nine square miles in the County of Ayr was selected for the experiment. This area contained 37 farms and of these the owners of three refused to participate and two others finally dropped out. At the commencement it was found that two of the herds were already tubercle free. At the end of three years out of the 30 herds participating in the scheme 28 are said to have made substantial progress, 20 being free from infection at the final test. The basis of the eradication measures was the isolation of reactors from nonreactors and the gradual replacement of the infected by free stock. The cost involved by owners in the eradication was small and was more than offset by the increased value of their stock. It was felt that the provision of better isolation accommodation would have accelerated progress in several herds.[*]

In 1929 a scheme was formulated by the Scottish Branch of the National Veterinary Medical Association of Great Britain and Ireland which contained

* Jordan, L., The Eradication of Bovine Tuberculosis, Medical Research Council Report, 1933, p. 14.

many suggestions incorporated in the present Attested Herds Scheme In view of present-day legislation it is interesting to describe the Scheme as elaborated The promoters pointed out that it should be a national scheme and must be controlled by the Government and they suggested that the Ministry of Agriculture and Fisheries should be the Central Department They stated that "The Branch recognises the progress which has been made in North America by the use of tuberculin and the slaughter of the animals, and also in Denmark and elsewhere by the method of dealing with the disease associated with the name of Bang In view of the probable percentage of reactors in British herds, it appears impracticable to apply the American plan immediately in any widespread campaign in this country The Branch has considered carefully the best means available for dealing with this problem of tuberculosis eradication, and believe a combination of the American and the Bang methods is best suited to the needs of this country" The essence of the scheme was that certain selected herds should be freed from the disease on a voluntary basis to act as a nucleus for tubercle-free stock The types of herd suggested for a commencement are —(a) Herds in which the incidence of tuberculosis is believed to be low ; (b) self-supporting herds ; (c) pedigree and milk-recorded herds, and (d) herds so situated as to facilitate the formation of "Accredited Areas" When reactors were numerous they suggested that provision should be made for their isolation, but when few in number they considered that they should be slaughtered and compensation paid to their owners The free herds were to be classed as ' Accredited,' and when a sufficient number of such were formed in any one district, it was suggested that those farmers who did not agree to enter the scheme willingly should be compelled to do so in order that the "Accredited Area" might be completed The Government were asked to set aside a sum of money annually for the purpose of the scheme, which would be used for (a) the cost of testing ; (b) compensation for reactors ; (c) the cost of disinfection of premises ; and (d) provision of, or alternatively, loans towards the provision of necessary temporary buildings for the isolation of reactors Finally, when large numbers of "Accredited Areas" were formed, the Government would have to insist on all herd owners in infected areas coming under the scheme An important point in this scheme was the fact that it was thought that it could be worked on a small or a large scale as desired, depending upon the amount of money available, for only those herds would have been dealt with in any one year for which the grant of money would be ample and sufficient

Tuberculosis (Attested Herds) Scheme—On the 2nd November, 1932, a committee of the Economic Advisory Council was appointed with the following terms of reference —"To consider what practical measures can be taken to secure an eradication of disease among milch cattle in this country, and to report upon any changes desirable in the existing administrative practice, and, in particular, upon the value and practicability of methods for reducing the incidence of bovine tuberculosis and improving the milk supply"

Following on the work of this committee, the Ministry of Agriculture and Fisheries on 1st February, 1935, brought in the Tuberculosis (Attested Herds) Scheme which applied to England and Wales and a similar scheme was set up for Scotland by the Department of Agriculture for Scotland These schemes make an historic landmark

in the policy of the Government towards the eradication of bovine tuberculosis. The farmer was offered free tuberculin testing and the bonus of 1d. per gallon for all milk sold through a Milk Marketing Board—but the conditions were very rigid and were much criticised as being beyond the power of attainment by the average farmer and the number of Attested Certificates did not grow sufficiently to warrant the original schemes. In 1936, the Scottish scheme was amended and that for England and Wales was also altered so as to overcome many of the difficulties of the former scheme in 1937. Again, as the result of the passing of the Agriculture Act of 1937 which gave the Minister of Agriculture power to expend such public funds as the Minister thinks fit for the purpose of securing so far as is practicable that a herd will be free from tuberculosis,* and following the setting up of the State Veterinary Service, both schemes were amalgamated from 1st April and amended from 1st July, 1938.

The Government, under the scheme, were prepared to undertake the testing with tuberculin of any herd of cattle in Great Britain in accordance with the conditions prescribed in the scheme, and if no reactor was found to issue a certificate of attestation in respect of the herd. The herd was then placed on the Register of Attested Herds and known as an attested herd.

During the next two years the number of attested herds increased considerably as shown in the following table :—

NUMBER OF ATTESTED HERDS AT END OF YEAR

	England	Wales	Scotland	Gt. Britain
1935	37	18	44	99
1936	83	109	222	414
1937	418	395	638	1,451
1938	1,189	2,340	1,115	4,644
1939	3,310	7,923	2,641	13,874
1940	3,820	9,289	3,185	16,294

At the outbreak of war however applications for attestation were accepted only from herds holding a licence for the sale of Tuberculin Tested milk and the number of herds in the scheme remained fairly constant until 1944. In that year the scheme was reopened to all herds without financial assistance towards the cost of qualifying tests and

* The power to make these payments was later extended by the Agriculture (Misc. Provisions) (No. 2) Act, 1940, and then by the Animals Act, 1948, which have now been consolidated in the Diseases of Animals Act, 1950. The current powers extend to 1958 with power to extend further, by order, by three successive periods of five years.

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without bonus payments   During the next six years further expansion took place —

NUMBER OF ATTESTED HERDS AT END OF YEAR

	England	Wales	Scotland	Gt Britain
1944	4,397	8 441	4,138	16,976
1945	5,272	9,147	5,617	20 036
1946	7,105	10,271	7,978	25,355
1947	9,445	11,099	9,892	30,436
1948	13,358	12,395	11,143	36,896
1949	18,838	13,818	12,233	44 889
1950	25,814	15,543	13,688	55,045

By the end of 1950 the proportion of attested cattle to total cattle in Great Britain was 23 per cent   A new Attested Herds Scheme came into operation on 1st October, 1950

In order to qualify directly for the scheme it is necessary for the owner of the herd to produce veterinary certificates of two completely clean tests of all cattle comprising the herd carried out at intervals of not less than 60 days and not more than 12 months between these tests. He must, moreover, satisfy the Ministry that the management of the herd and the conditions under which it is kept are suitable and he must also undertake to comply with the conditions and rules of the scheme If all is satisfactory the herd then becomes a Supervised Herd and an official test will be carried out not less than 60 days after the second of these two qualifying tests   If no reactor is disclosed at the official test then the herd is placed on the Register of Attested Herds If any reactor is found at this test, it must be removed immediately and the premises disinfected , a second test will be applied to the herd after a further 60 days and if there are no further reactors the herd is admitted to the Register   So long as there are reactors, however, the process must be repeated until a clean test is obtained, the herd remaining Supervised throughout this period   All such official tests are carried out free of charge to the owner Whenever reactors appear the premises must be disinfected in the approved manner   Subsequent tests in attested herds are applied periodically at the discretion of the Ministry The compulsory testing of goats and swine at the owner's expense may be asked for by the Ministry, together with the segregation of these animals when considered necessary

In order to encourage participation in the scheme a bonus, paid either on the milk produced or on the number of animals in the herd, is payable for the first six years after entry

Special permits are required for the movement of animals to and from attested and supervised herds and unless an animal comes directly from an attested herd it must be isolated and tested by the Ministry after 60 days of its entry into the isolation premises.

For full details a copy of the Tuberculosis (Attested Herds) Scheme, 1950, should be consulted.

The single intradermal comparative tuberculin test is the test now employed for all official tests.

Area Eradication. Under the Agriculture Act of 1937 it was laid down that the Minister could make Orders :—

(a) declaring any area as respects which he is satisfied that a substantial majority of the cattle therein are free from any particular disease to be an eradication area for purposes connected with the control of that disease ;

(b) declaring any area as respects which he is satisfied that any particular disease of cattle is for practical purposes non-existent therein to be an attested area for purposes connected with the control of that disease ; and

(c) prohibiting or regulating the movement of cattle into, out of or within any area which is for the time being an eradicating area or an attested area.

The Tuberculosis (Area Eradication) Order, 1950, which came into operation on 1st January, 1951, is made under the above Act.*

On 1st October, 1952, two areas of Great Britain, one in S.W. Scotland and the other in S.W. Wales, will be declared eradication areas and compulsory testing of all herds in those areas which are not already attested will come into operation together with movement restrictions. Orders have also been made for the compulsory slaughter of reactors and payment of compensation in respect of each animal slaughtered. In the meantime free-testing facilities are available in these areas and will also be available in areas which hold out good prospects of being declared eradication areas at an early date. Such free-testing facilities will not be available in a particular area until there is already in that area a high percentage of herds registered under the Attested Herds Scheme.

When all the cattle in an eradication area have been tested and the reactors slaughtered and it then appears that bovine tuberculosis, for all practical purposes, no longer exists in that area, the area will be declared an attested area. Here, the general conditions will be similar to those in eradication areas but freer movement will be per-

* This section of the Agriculture Act, 1937, is now consolidated in the Diseases of Animals Act, 1950.

—V.H. 28

mitted between premises within the area   The first areas to be declared attested areas are the county of Zetland, the Isles of Scilly and the islands of Arran and Great and Little Cumbrae in the county of Bute

FOWL PEST

The form of fowl pest known as Newcastle disease was first recorded in Great Britain by Doyle* in 1927

A second outbreak was seen on a single large farm in Hertfordshire in 1933 but was eradicated by means of slaughter The disease appeared again in 1947, since which date many serious outbreaks have occurred

Elsewhere the disease has been recorded in many countries and is widespread on the continent of Europe

Primary outbreaks in this country have undoubtedly originated from the feeding of unsterilized swill containing offal and trimmings from poultry carcases imported from abroad †

The classical form of Newcastle disease is an acute highly virulent disease in which symptoms of dullness, loss of appetite, diminished egg production, respiratory distress with a pronounced "gurgle," distended crop, yellowish green diarrhoea and cyanosis of the comb and wattles are generally followed by death fairly rapidly Birds which survive for some days often develop nervous symptoms, tremors, paralysis of the limbs or torticollis

More recently a milder type of the disease has been observed in which the symptoms are less distinctive and the mortality is only slight. This form, however, is still highly infectious and causes considerable loss in egg production

Control. Under the Fowl Pest Order of 1936, as amended by the Fowl Pest (Amendment) Order of 1947, suspected cases of the disease must be reported by the owner, or by the veterinary surgeon encountering such a case, to a police constable The police constable transmits the information to the Ministry's Divisional Veterinary Officer who arranges for an investigation

If the presence of the disease is confirmed, the following are the principal rules which come into operation —

No live poultry may be moved in or out of the premises

No carcase may be moved without licence

No hatching eggs, foodstuffs, litter, droppings, utensils, food bags, crates, hurdles or poultry appliance or vehicle to be removed except under licence

All droppings, litter and waste food must be disinfected before

* Doyle, T M (1927) *J Comp Path* **40**, 144
† See Boiling of Animal Foodstuffs Order of 1947, page 422.

being removed from any building, yard, or other place in which affected birds are housed or have recently been kept.

No one except an Inspector of the Ministry or of the Local Authority or the attendant is permitted to enter or leave the infected place, and they must wear suitable overalls and boots which must be cleansed and disinfected before leaving.

The Order gives the Minister power to slaughter any affected or suspected birds and any others which have been in contact or have been in any way exposd to infection. Compensation is payable for all unaffected birds slaughtered.

All utensils, appliances, vehicles and premises with which affected or suspected birds have been in contact must be disinfected with a 4 per cent. solution of sodium carbonate (washing soda) in water (approximately $6\frac{1}{2}$ ozs. per gallon).

There is also provision allowing the Ministry, in the event of the owner failing to carry out proper disinfection, to cause it to be done and to recover the expenses from the owner.

Restriction of movement of live poultry exposed to infection may be enforced by an inspector of the Ministry or of a local authority who suspects the presence of the disease.

In the severe outbreaks which have occurred during recent years it has been necessary for the Ministry from time to time to make standstill Orders restricting the movement of live poultry over large areas where the disease is prevalent. This has been particularly necessary since there is evidence that the movement of birds from markets, dealers' premises and shows has been responsible for many outbreaks of fowl pest.

The Fowl Pest Order of 1936 applies to the disease known as fowl plague as well as to Newcastle disease. Fowl plague has not been recorded to any extent in Great Britain but causes serious losses in Egypt, Palestine and India.

REGULATIONS FOR THE PREVENTION OF THE INTRODUCTION OF DISEASE INTO GREAT BRITAIN*

In order to prevent as far as possible the introduction of disease into Great Britain legislation has been made placing restrictions on the importation of animals, poultry, carcases, hay and straw, and therapeutic substances.

Cattle, Sheep, Goats, other Ruminants and Swine. The Diseases of Animals Act, 1950, which consolidates previous Acts, prohibits absolutely the landing in Great Britain of any cattle, sheep, goats

other ruminants or swine brought from any country abroad with the following exceptions —

(a) Animals from Northern Ireland, Eire, the Channel Islands and the Isle of Man   Landing of these is permitted under certain conditions which include, in general, veterinary examination at the port of shipment and at the approved landing place and, unless they are intended for immediate slaughter, they must be detained at the place of destination for six days in the case of cattle, sheep and goats, and for twenty-seven days in the case of swine   (The Animals (Landing from Ireland, Channel Islands and the Isle of Man) Order of 1933)

(b) Fat Stock for slaughter at the port of landing from countries not scheduled as "prohibited countries"   The only countries not "prohibited" are Canada, Australia, New Zealand, United States (swine are prohibited) and the Faroe Islands   Landing must be at an authorised Imported Animals Wharf used for no other purpose   (The Animals (Importation) Order of 1930)

(c) Cattle born and reared in the Dominion of Canada, subject to veterinary inspection before shipment and on arrival, certification of freedom from cattle-plague, pleuro-pneumonia, foot-and-mouth disease and mange at time of shipment, and detention for six days at their destination   (Diseases of Animals Act, 1950, and Importation of Canadian Cattle Order of 1933)

(d) Registered pedigree cattle, sheep, goats or swine from any of the Dominions subject to veterinary examination before shipment and on landing and quarantine for a specified period on arrival in this country

(e) Animals intended for exhibition or other exceptional purposes   Importations under this provision are mostly zoological specimens for permanent detention in zoological gardens

Horses, Asses and Mules.   Under the Importation of Horses, Asses and Mules (Great Britain) Order of 1938 any horse, ass or mule may not be landed, except from Northern Ireland, Eire, the Channel Islands and the Isle of Man, unless accompanied by a certificate of an authorised veterinary officer of the Government of the country of origin certifying that the animal is free from glanders, epizootic lymphangitis, ulcerative lymphangitis, dourine, horse pox, sarcoptic or psoroptic mange, influenza, ringworm, strangles, infectious equine anaemia or encephalo myelitis , that the animal has passed the mallein test within ten days before shipment , and that the animal has not been in contact with infectious equine anaemia during the previous six months or with encephalomyelitis during the previous twenty-eight days

Thoroughbred horses, polo-ponies, performing animals and animals

intended for exportation within fourteen days are exempt from the mallein test as are animals from Iceland or the Faroe Islands.

Dogs and Cats. The landing in Great Britain of any dog or cat or other canine or feline animal is prohibited except with a licence from the Ministry requiring six months quarantine at an approved premises. No such licence is required in the case of animals from Northern Ireland, Eire, the Channel Islands and the Isle of Man. Any dog or cat which is not from one of these exempted places and for which a licence has not been obtained, cannot be landed and must be kept locked up in a place from which it cannot escape (on the vessel) or, alternatively, in the case of a dog, it must be muzzled and kept tied up on the ship. (Importation of Dogs and Cats Order of 1928).

Carcases. There is an embargo on the importation of fresh carcases from the continent of Europe, Iceland, Northern Ireland, Eire, the Channel Islands, and the Isle of Man excepted. The importation of Carcases (Prohibition) Order of 1926 and its subsequent amendments should be consulted for details of various animal products covered by and exempted from this embargo.

Poultry and Hatching Eggs. Under the Poultry and Hatching Eggs (Importation) Order of 1947, no live poultry or eggs for hatching may be imported into Great Britain without a licence unless they come from Eire, Northern Ireland; the Channel Islands or the Isle of Man.

The importation of poultry carcases from countries where fowl pest is known to occur is also subject to restriction under the Poultry Carcases (Importation) Order of 1950.

Meat Wrappers. The Importation of Meat, etc. (Wrapping Materials) Order of 1932 is designed to prevent the use of wrappers from imported meat for other purposes, such as the manufacture of bags for animal feeding-stuffs or for fertilizers, which might result in the spread of foot-and-mouth disease should the imported meat be from affected animals. Meat wrappers from certain countries are exempted from the Order. The type of materials which may be used are defined in the Order ; they are materials which are either unsuitable for subsequent use in the manufacture of bags or are of a design which can be readily recognised should an attempt be made so to re-use it.

Hay and Straw. There are restrictions on the landing of hay and straw in Great Britain except when used as packing materials or as fodder or litter for animals imported under Ministry licence, Certain

countries are exempted. (Foreign Hay and Straw Order of 1912) Hay and straw used for packing purposes must not subsequently be brought into contact with animals. (Foot-and-Mouth Disease (Packing Materials) Orders of 1925 and 1926.)

Therapeutic Substances. The Diseases of Animals (Importation of Therapeutic Substances) Order of 1936 prohibits the importation into Great Britain of vaccines and sera intended for veterinary purposes unless the bottles are labelled so as to show the exact nature of the contents and the place and country of preparation. The importation of contagious abortion vaccine is prohibited except under licence and licences are only issued for dead vaccine.

SOME FURTHER REGULATIONS TO CONTROL THE SPREAD OF DISEASE IN GREAT BRITAIN

Boiling of Animal Foodstuffs. Under the Diseases of Animals (Boiling of Animal Foodstuffs) Order of 1947 all meat, bones, etc., all swill and all waste foodstuffs which have been in contact with meat or bones must be boiled for at least one hour before being fed to animals or poultry. The Order is designed to prevent the spread of foot-and-mouth disease, swine fever and fowl pest.

Markets, Sales and Lairs Orders of 1925, 1926 and 1927. These Orders require that as soon as possible after use all premises used for sales shall be cleansed and disinfected in the approved manner. If the ground surface is not impervious to water there must be an interval of twenty-four days between one sale and the next, but this rule may be modified by licence in certain cases, *e.g.* seasonal sales of cattle and sheep.

Poultry Markets and Receptacles (Disinfection) Orders of 1936 and 1937. The cleansing and disinfection of all pens and fittings used for poultry at markets and sales and of receptacles used for the conveyance of poultry is required under these Orders. A 4 per cent. solution of washing soda is the disinfecting agent to be used for the purpose and the disinfection must be carried out as soon as possible after use. Under an amendment of 1937 receptacles used for racing pigeons are exempted.

The Poultry (Exposure for Sale) Order of 1937. This Order enables action to be taken against any person who exposes for sale poultry which are in an obvious state of ill-health without the necessity for defining or diagnosing the nature of the disease from which the birds may be suffering.

The Warble Fly (Dressing of Cattle) Order of 1948. This Order supersedes an earlier Order which was suspended during the war years and requires that all cattle visibly infected with warble fly maggots are to be treated with a prescribed derris dressing at intervals of not more than thirty-two days during the period from the fifteenth of March to the thirtieth of June. The Order is designed to reduce the considerable loss of leather resulting from the damage caused by warble fly maggots.

NON-NOTIFIABLE DISEASES

Correct hygiene can play a large part in the control of many diseases of animals which, though not notifiable, are of considerable economic importance. In general the procedure to be adopted in regard to isolation, cleansing, disinfection and other precautions will be on a basis of the general principles outlined at the beginning of this section, and will only vary in accordance with our knowledge of the virulence, habitat and method of spread of the organism concerned.

A few of the more important non-notifiable diseases which present particular problems are briefly referred to below.

BOVINE CONTAGIOUS ABORTION

The cause of bovine contagious abortion, sometimes known under the names of Bang's disease and brucellosis, is *Brucella abortus*. Other bacteria are sometimes associated with abortion in cattle, notably *Vibrio foetus*, *Corynebacterium pyogenes*, *Mycobacterium tuberculosis*, streptococci and other bacteria, and occasionally moulds. Abortion in cattle is also caused by the protozoan parasite, *Trichomonas foetus*.

Bovine contagious abortion has been recognised from ancient times as a serious cattle disease. It occurs in all closely-settled countries, and is known to be present in most parts of the world where there is any considerable cattle population.

Br. abortus is killed by heating at 60° C. for ten minutes. Efficient pasteurisation thus kills it with certainty. Ordinary disinfectants kill the organism quite easily. When protected from adverse influences— heat, desiccation, sunlight, etc.—it is able to live for considerable periods in many of the ordinary situations in which it is likely to arrive along with contaminated material.

Distribution of Br. Abortus. In the bodies of affected animals its distribution may be as follows:—

Barren Cows.—The udder and, to a more limited extent, certain lymphatic glands—notably the supramammary and pelvic glands and

sometimes those related to the pharynx—and occasionally the spleen, are the most usual situations in which *Br. abortus* is found ; it is found in certain enlarged bursal lesions.

Pregnant Heifers and Cows.—Pregnant heifers and cows provide one medium for the most striking manifestation of the activities of *Br. abortus* infection, the capacity to cause abortion as the result of invading the pregnant uterus. The uterine cavity in barren animals is usually sterile, but as the placenta develops in infected cattle, the organism migrates to the uterine cavity and multiplies vigorously. It is abundantly present in the exudate that forms between the uterine wall and the chorion, and invades other tissues of the placenta ; it is present in the contents of the foetal stomach. The organism is excreted in the uterine exudate for a few days, but with few exceptions it is absent from this source by the end of the third week after abortion or calving.

Calves.—Immature animals as a rule scarcely react to the presence of *Br. abortus*. In calves in infected herds it can often be demonstrated in the lymphatic glands related to the pharynx, but the animals usually eliminate it soon after removal from contact with the organism, and provided that they are kept away from infection and pass the agglutination test before they are sexually mature, they can be introduced into clean herds. From experimental work on the question, it is inferred that usually calves are not really susceptible to infection until the genital organs approach maturity.

Bulls.—The bull is susceptible to infection, and while few observers consider that the bull is a major agent in the spread of the disease, it is recognised that *Br. abortus* in bulls may be responsible for the infection of cows. Evidence has been accumulating that lesions of the epididymis and testicle due to *Br. abortus* are not uncommon and that they are often so serious as to impair potency or render the animal useless for stud purposes. The organism has been demonstrated in the semen.

Methods of Infection. At the end of the last century it was widely believed that infection of the cow occurred chiefly from the bull at coitus. Later, experimental work demonstrated that infection easily occurs from ingestion, and this is now considered to be the commonest method. It has been shown that infection easily occurs via the conjunctiva and also that it can occur through the skin, but the extent to which these paths of infection operate in practice is unknown ; in any case, their existence has little influence upon the methods to be used for the control of the disease.

The excretion of the organism naturally depends upon its location in infected animals ; most of the infection is derived from the infected foetus, placenta and uterine exudate. These are the materials in which really large numbers of the organism are likely to gain access to situations from which they can infect other cattle, and it is important to remember that, in infected animals, these materials are as likely to be infected in cows that calve normally as in those that abort. The organism is very commonly present in milk, but in smaller numbers than in material from the genital organs.

Methods of Control. In Great Britain two methods of control have been practised, *viz.*, by blood testing and either disposal or isolation of reactors, and by vaccination. In the United States, where the incidence of the disease is said to be lower than here, blood testing and slaughter of reactors was followed for a time, but even in the United States this method has had to be abandoned or modified because of the high costs involved in indemnifying owners for their slaughtered stock.

Eradication by blood testing and Segregation of Reactors.—This method involves the blood testing of the herd at frequent intervals and the segregation and ultimate disposal of animals which have been shown by the test to be infected. This is the ideal method of control but its application generally in this country is limited by economic difficulties and lack of the necessary facilities for ensuring success. Moreover, the aim of eradication is not only the elimination of infection from a herd but the subsequent maintenance of its freedom from infection.

This method is most likely to be successful in self-contained herds in which the incidence of infection is not high and where the introduction of accidental infection from outside sources, *e.g.*, neighbour's cattle, can be avoided. The arrangements available must be of such a nature that either the reactors will be removed from the farm as soon as possible after detection, by sale or transfer to a separate farm, or isolated in separate buildings where precautions can be ensured against the transfer of the infection from the reacting to the non-reacting section of the herd. The first two arrangements will give the quickest results, but the most important of all requirements is the unremitting care and attention of the owner, stockman and all concerned with the cattle. One single act of negligence in the care of the non-reacting herd may result in the undoing of the efforts of several years.

Many valuable herds with a high standard of management have been freed from infection by this method, and at one time high hopes

were held of the method becoming of more general application, but subsequent experience has shown that effective isolation of the infected animals is almost impossible of achievement on most farms, even when separate sheds and fields are available for the reactors. It would now appear that informed opinion has accepted the view that eradication of contagious abortion by blood testing and segregation is impracticable as a measure of general application to all infected herds, and to-day vaccination is widely advocated in this country and in the U.S.A. as the most helpful means of controlling the disease.

Vaccination.—In the past several different types of vaccine have been used for the inoculation of cattle with the idea of preventing or limiting the spread of contagious abortion. Some of these vaccines were suspensions of live *Br. abortus* organisms which under certain circumstances, *e.g.*, if injected into pregnant animals, were fully capable of producing abortion but which, when given to non-pregnant cattle, conferred on them a considerable immunity to the act of abortion. Live vaccines of this type did undoubtedly reduce the number of abortions in an infected herd, but they had the serious disadvantage of maintaining infection in the herd.

Experimental work in the United States of America with strains of *Br. abortus* of different degrees of virulence resulted in the production of Strain 19 which shows high antigenicity and low pathogenicity. Strain 19 vaccine was introduced into Great Britain in 1942 and is now generally adopted as the vaccine of choice.

Calfhood Vaccination.—In the U.S.A. Strain 19 has been used mainly for the vaccination of calves, and the evidence for the efficacy of the vaccine in preventing abortion when the animals reach breeding age was drawn from an extensive field trial in 260 infected herds, containing approximately 19,000 cattle. The results of the trial were considered to be sufficiently successful to warrant the adoption of calfhood vaccination by the U.S. Bureau of Animal Industry on a national scale as an aid to furthering its official policy of eradication. A number of field experiments were also carried out in this country, and the results of these, together with those obtained on a much large scale in the U.S.A., led the Ministry of Agriculture to sponsor a Calfhood Vaccination Scheme on a wide scale. Only female calves between the age of four and eight months are vaccinated, although the vaccination of older calves is not necessarily excluded. Shortly after vaccination, the treated calves become positive reactors to the blood agglutination test and remain so for a variable period, but the majority become nor-reactors by the time of their first calving.

The purpose behind the vaccination of calves is to build up an immunity at a time when the calf is comparatively resistant to

permanent infection with *Br. abortus*. This immunity persists beyond calfhood, but there is still some doubt as to the exact duration.

The Calfhood Vaccination Scheme has now been in operation since December, 1944, and there is no doubt that it has done much to reduce losses from contagious abortion in Great Britain.

Adult Vaccination.—The evidence obtained through experimental and field work both here and in the U.S.A. indicates that the increased resistance to contagious abortion infection resulting from the vaccination of sexually mature cattle is at least equal to that produced in calves. Many practitioners use "whole herd" vaccination (*i.e.*, vaccination of all females irrespective of age) as their sole method of controlling abortion and are satisfied with the results.

As the duration of the immunity resulting from calfhood vaccination is the subject of some doubt, revaccination after the first and second calvings is frequently practised.

Disinfection. The need for proper hygienic precautions, even when vaccination is being practised, must be emphasised, since a heavy infection might overcome the immunity provided by the vaccine. If an abortion occurs, the cow should be isolated until all discharges have ceased and the aborted foetus and foetal membranes should be destroyed by burning, or by burial at a place to which cattle have no access.

Contaminated bedding should be similarly disposed of. If the abortion occurs at pasture, any turf which has obviously been subject to contamination should be removed. Disinfection of the stall or loose-box should be thorough, paying particular attention to walls and fittings likely to have been contaminated with uterine discharges. Two per cent. caustic soda or a three per cent. cresol solution may be used.

Legislation. The only legislation in this country dealing with the disease is the Epizootic Abortion Order of 1922.

This Order prohibits the exposure in markets, sale yards, etc., of cows or heifers which to the owner's knowledge had calved prematurely within two months preceding the exposure. It prohibits the sale of such animals, unless notice is given to the purchaser in writing of such premature calving. It makes it unlawful for any person to send to a bull for service a cow or heifer known to have calved prematurely within the two months immediately preceding, unless notice is given in writing of such premature calving to the owner of the bull. The Order also makes it unlawful for the owner of animals which have calves prematurely within the two months to turn them to graze on any common or unenclosed land, on fields, etc., which are not sufficiently fenced to prevent cattle entering or escaping, or to graze

them at the side of a highway or on any land on which there are cattle which are not the property of the owner of the animals which had calved prematurely.

Unfortunately, it cannot be said that this Order has played any effective part in the control of the disease.

BRUCELLA MELITENSIS

Up till 1940, *Br. abortus* was the only type of Brucella to be isolated in Great Britain from an indigenously infected animal or human being. In that year, however, Menton* isolated a *Brucella* organism from a guinea-pig that had been inoculated six weeks previously with the mixed milk of an Accredited herd in the Midlands which was subsequently identified as belonging to the *Br. melitensis* type.

As this organism gives rise to undulant fever in man, this discovery was the cause of some alarm in both public health and agricultural circles and prompt action was taken to deal with the situation by the slaughter of the cows which were secreting the organism in their milk together with those animals, including sheep and pigs, which had been in contact with them. To do this a special Order of the Minister of Agriculture was necessary.

Since 1940 several isolated instances have been reported in which this organism has been recovered from the milk of cows and the Order has been applied in each instance. There is no evidence that undulant fever in man has resulted from drinking milk infected with the organism and it is considered probable that the organism is one which, while behaving under laboratory test like *Br. melitensis*, has not all the features of that organism, particularly in regard to pathogenicity.

Legislation. The Brucellosis Melitensis Order of 1940, which came into operation on the 3rd July, 1940, provides that the Minister of Agriculture "may, if he thinks fit, cause to be slaughtered any animal which in his opinion is affected with brucellosis melitensis or has in his opinion been in any way exposed to the infection of that disease."

BOVINE MASTITIS

Bovine mastitis (inflammation of the mammary gland) is a cause of very considerable economic loss. It usually results from bacterial invasion of the mammary tissue but other factors may act as predis-

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* Menton, J. (1940). *Med. Offr.* 63, 33-35,

posing causes and in some cases showing obvious symptoms no organisms can be demonstrated. The bacteria responsible for mastitis include streptococci, staphylococci, *Corynebacterium pyogenes*, *Mycobacterium tuberculosis*, *Bact. coli* and related groups.

Streptococci cause the great majority of cases of mastitis. Streptococcal mastitis, due to *Str. agalactiae*, runs an essentially *chronic* course, although at times it may be met with in an acute form. The disease has no appreciable effect upon the general health, and changes in the gland are often not apparent on casual observation. The disease is insidious in its onset, is usually slowly progressive over several lactations, and the gradually-increasing fibrosis which results leads to destruction of milk-secreting tissue, and the development of the well-known "light quarter," or to complete functional loss of one or more quarters. During the quiescent stages of the disease the characters of the milk may be unchanged to the naked eye or there may only be small clots, which are sometimes confined to the first streams drawn. More active signs of the disease are liable to appear if the animal is subjected to some disturbance such as incomplete milking or exposure to adverse climatic conditions, or if the animal is ill from some other cause. The udder then becomes swollen and the milk converted to a whey-like fluid containing clots. With frequent and thorough stripping-out, these signs are likely to disappear and in a few days the milk as a rule regains its normal appearance. For this reason, and also on account of the apparently mild nature of the affection and of the slight disturbance to the animal's general health, owners are often under the erroneous impression that the disease is of small importance. This is unfortunate, because apart from other reasons to be mentioned later, it is now well recognised that diseased cows usually carry the infection over several lactation periods and rarely show complete recovery.

Str. dysgalactiae, Str. uberis and *Str. zooepidemicus* are responsible for a smaller number of cases than *Str. agalactiae*, many of which are clinically indistinguishable from cases due to that organism. Some of these infections, however, are acute, especially those due to *Str. dysgalactiae* and *Str. zooepidemicus*, and in these cases there may be rapid loss of a quarter or, on the other hand, complete recovery in a few days.

Mastitis due to pathogenic (toxigenic) staphylococci occurs in two forms, acute and chronic. In the acute form, which though relatively infrequent, diagnosis is easy. The animal is acutely ill, parts of the udder tissue become gangrenous, and such secretion as can be obtained consists of a thin reddish-brown liquid like haemolysed blood. Many affected animals die, owing to the absorption of toxins from the udder. In its chronic form the changes produc ̣ e gland are similar

in nature to those of chronic streptococcus mastitis, though tending to be less severe, and gross changes in the milk are less liable to occur.

Corynebacterium pyogenes produces a *suppurative* form of mastitis which sometimes occurs in epidemic form and is especially prone to attack dry cows and virgin heifers during the summer months. For these reasons this form is often referred to as epidemic mastitis or summer mastitis. Other organisms, *e.g.*, *Str. dysgalactiae*, may be responsible for this form of mastitis.

Pathogenisis. In connection with the origin of cases of mastitis, there are several factors which are commonly regarded as rendering animals more liable to attack. Important as many of these factors undoubtedly are, they are subsidiary in the sense that they are unable to exert their full effect in the absence of disease-producing bacteria. Among such external factors may be mentioned any which cause damage to the milk-secreting tissues, such as stagnation of milk within the udder following incomplete milking or the practice of "over-stocking." Direct injuries to the gland act as predisposing causes, *e.g.*, rough milking, injuries to the teats from the teeth of the calf during suckling or from treads, injuries to the udder from horns, pressure upon the udder through the cow lying upon an uneven floor. The improper use of the milking machine either as a result of an incorrect vacuum or wrong pulsation rate, or by leaving the teat cups on after the milk has ceased to flow, may frequently be a factor in damaging the tissues and thus predispose to mastitis.

It may be noted that mastitis occurs more commonly in the hind quarters of the udder than in the fore quarters, possibly owing to the larger size of the hind quarters and their consequent greater liability to injury. What may be called climatic agencies are of importance, *e.g.*, chills from lying on cold, wet flooring ; draughts, and wide variations in temperature to which animals accustomed to cool outdoor surroundings are exposed when kept in stalls for some reason during warm days in summer. It is well known that animals are liable to suffer from mastitis during the course of or following other diseased conditions, such as foot-and-mouth disease and retained placenta.

With regard to the way in which an animal becomes infected with mastitis, it is necessary to point out that a method which may operate in one form of the disease may not do so in another form. For instance, while there is every reason to believe that the common form of streptococcus mastitis is chiefly spread by the hands of the milker,[*] such an explanation cannot hold with summer mastitis where, as a

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[*] See "Modes of Spread of *Streptococcus Agalactiae* Infection in Dairy Herds." Imp. Bureau An. Health Rev. Publ. No. 2, 1944.

rule, the teats have never been handled by the milker. In summer mastitis it is commonly supposed that flies act as transmitting agents, and it is possible that other environmental factors play a part in its development.

The Importance of Mastitis. Disease of the udder in cows is of importance, largely on account of its wide prevalence, particularly the chronic streptococcal form which occurs in milking cows. Mastitis is by no means confined to herds in which the standard of cleanliness is low, and in fact the incidence is sometimes above the average in herds where the conditions for clean milk production are beyond reproach. Probably it would be justifiable to take a figure between 20 and 30 per cent. as a conservative estimate of the general incidence of bovine mastitis in countries where milk production is intensive.

The streptococci ordinarily associated with mastitis *(Str. agalactia)* are harmless when ingested by human beings. In view of the amount of raw milk contaminated with these organisms which is consumed daily without ill effect, it is impossible to believe otherwise. In the past, however, a number of epidemics of scarlet fever and septic sore throat have been traced to contaminated milk supplies due to an actual infection of the cow's udder with pathogenic streptococci which in the first instance were derived from human beings.

So far as the milk supply is concerned, mastitis causes a reduction in the yield, and it also has an adverse effect upon the quality of the product. "Low milk yield" is put down as one of the major causes of excessive wastage in herds, and there can be little doubt that low yield is largely occasioned by actual disease of the udder. Unfortunately, chronic streptococcal mastitis is chiefly found in cows over 4 or 5 years of age, *i.e.*, in animals which should be reaching the peak of their milk-producing capacity. So far as the quality of the milk is concerned, the secretion from chronically inflamed quarters, in which the disease has progressed to a certain point, is deficient in fat and lactose and contains an excess of chlorides, as well as reaction products such as blood protein and leucocytes. Such milk has an unpleasant salty taste, imparts a disagreeable flavour to butter, and also creates difficulties in cheese-making inasmuch as it does not undergo the normal lactic fermentation.

Control of Mastitis. In the control of *chronic streptococcal mastitis* a good deal hinges on the question of diagnosis. In this form, latent infections, which are not readily detectable clinically, are extremely common; unless such cases are picked out and suitably dealt with,

there is no hope of properly controlling the disease. In connection with diagnosis a number of cases can be picked out in the cow-shed by considering the history of the cow, by palpating the gland and by applying simple tests to the milk ; where these methods fail or give an uncertain answer the milk must be examined in a laboratory. Thus, the owner or herdsman may be aware that the cow has shown signs of mastitis. A history of sudden variations in the milk yield in the absence of other causes, and especially if the fall in yield is confined to one or two quarters, will raise a strong suspicion of udder disease. When the milk is examined in the cow-shed a little of the force milk from each quarter may be drawn into a shallow dish with a blackened surface and inspected for the presence of fine clots. This may be supplemented by the brom-cresol-purple test, in which filter paper impregnated with this chemical substance is wetted with the milk of each quarter. A purple colour on the paper indicates that the milk is abnormally alkaline and *in the cow in full milk* this points to a disturbed condition of the quarter. Milk of normal alkalinity produces a slate-grey colour on the paper. In the laboratory the milk may either be sown directly on to culture plates or it may first be incubated overnight and then examined microscopically or culturally.

The aim, therefore, of diagnostic methods is to pick out cows suffering from streptococcal mastitis in the latent form. When such cows have been detected, control measures having a definite chance of success may be proceeded with. The essential point here is that infected cows must be milked last. For this purpose it is usually most convenient to group them together in the milking shed, but it is unnecessary to isolate them when at pasture.

The predisposing causes mentioned in an earlier part of this article should be avoided as far as possible and, in the same connection, the following general hygienic precautions will always be important. Cows and their stalls should be kept as clean as possible. Milkers should wash their hands frequently and, where practicable, before milking each cow. The habit of moistening the hands with milk is to be condemned. Towels which have been used for wiping the udders of diseased cows should not be used for healthy animals. Infective discharges from the udder should not be milked on to the ground, but should be collected and destroyed. All possible precautions should be taken to prevent injuries to the udder and teats. Teat injuries in fact have proved to play an important part in the spread of mastitis ; for their prevention the teats should be made reasonably dry after milking and in the same connection the provision of sufficient floor space is not only humane but wise. Sores on the teats should receive prompt treatment, even though at first they may appear to be

"Chloros" solution in the bucket The second bucket and its cloths are used alternately for wiping and drying The solution in each bucket must be changed after cleaning 18 cows

The method recommended for disinfection of teat cups between milking of cows is as follows —After milking a cow and before milking another (1) rinse the cluster of cups in a bucket of clean cold water by plunging vigorously, mouths of the cups downwards, four times in five seconds The vacuum must be turned off Change this water after every three cup clusters (2) Drain for 5 seconds Dip into a second bucket containing "Chloros" solution, plunging three times in four seconds (3) Drain, shaking the cluster for 3 seconds. Renew the "Chloros" solution after 28 cows

The disinfection of milkers' hands is also carried out with "Chloros," viz ,—After washing off the dirt, rinse the hands thoroughly in the solution between the handling of each cow, when using the strip cup, before milking, and also between strippings

The *treatment* of mastitis has been revolutionized in recent years by the use of sulphonamides and penicillin The treatment now most frequently adopted for *Str agalactiae* mastitis is penicillin in an oil-wax base introduced directly into the quarters By such treatment of all cows in the herd, whether infected or not, and disinfection of the cows and premises, it is possible to eradicate the infection from the herd Stableforth, Hulse, Chodkowski and Stuart* have described its successful eradication from several herds by this method All quarters of all cows were treated with 100 000 units of penicillin on five successive days Penicillin cream was used on the workers' hands and cows teats for 14 days from the commencement of treatment On the morning of the fifth day the cows were disinfected with hypochlorite solution and the premises with cresol solution Though infection reappeared in two herds, seven herds have remained free

Str dysgalactiae, *Str uberis* and haemolytic staphylococci are present at sites other than the udder and thus these infections cannot be eradicated by such means though the incidence may be considerably reduced

JOHNE S DISEASE

Johne's Disease is a chronic contagious disease of cattle, sheep and goats caused by *Mycobacterium paratuberculosis* (Jone's bacillus) The organism is found in the intestine and in some cases in the mesenteric and other lymphatic glands of affected animals and is excreted in the faeces The disease is world-wide in its distribution

* *Vet. Rec* (1949) 61, 357

There is considerable evidence that, in cattle, infection in most cases occurs in the very young animal but symptoms do not become apparent until adult life. It is probable that many infected animals never reach the stage of clinical breakdown but by their excretion of the organism constitute a danger to susceptible stock.

The symptoms shown by cattle at advanced stages of the disease are emaciation with persistent foetid diarrhoea, the faeces being watery and frothy. The appetite is variable but may be good until shortly before death.

Control. Confirmation of a diagnosis of Johne's disease is dependant upon the detection of typical clumps of Johne's bacilli in a faeces smear stained by the Ziehl-Nielsen method. There is no reliable method yet available for the diagnosis of pre-clinical cases though the reaction to intradermal johnin or avian tuberculin may be an indication of infection.

Prophylactic measures depend on the avoidance, as far as possible, of contamination of food and water supplies. It is especially important that young stock be protected from infection and, where possible, they should be reared on premises separate from those upon which affected adult stock are kept. Calving should take place in a box which has been cleansed and disinfected and the litter must be kept as free as possible from faecal contamination from the dam. Calves should be moved to clean premises at birth and colostrum fed from the bucket, great care being exercised to avoid faecal contamination during its collection. Similar care should be taken with regard to the milk which is subsequently fed to the calves. Separate attendants should be provided for calves and adult stock and every precaution taken to avoid transference of infection from adult to young stock by indirect means.

Ponds in fields grazed by cattle are a potent source of danger in the transmission of Johne's disease. They should be filled in or railed off and an alternative, protected water supply provided (see page 62) ; the development of pools of water in the farmyard and approaches to buildings should be avoided by proper surfacing and drainage. Manure should be spread on arable land and not on grass. Contaminated pastures should be ploughed up or kept free of susceptible animals for at least six months and for a year if possible.

CALF DISEASES

Constant attention to hygiene is essential if losses are to be avoided in the rearing of calves. The commonest disease of young calves, white scour, generally manifests itself as a septicaemia associated with *Bact. coli* and predisposing factors undoubtedly play a large part in its

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occurrence. In the control of white scour it is of primary importance that the calf should receive colostrum as soon as possible after birth so that it may be fortified by the antibodies and vitamin A contained therein. Regular feeding and good housing with, in particular, the avoidance of cold and damp are likewise necessary. When bucket-feeding is employed the cleansing and sterilisation of utensils in between feeds must be scrupulously carried out. Steam sterilization in the dairy chest is the most satisfactory method.

Navel-ill or joint-ill is another septicaemic condition which may occur in young calves. The disease may be very acute and a pasteur-ella-like organism has been associated with such cases. In the less acute form *Corynebacterium pyogenes, Fusiformis necrophorus* or a haemo-lytic streptococcus may be responsible. The thorough cleansing and disinfection of calving boxes before and after parturition is of great importance in the prevention and control of this condition.

Amongst other diseases of calves to the development of which faulty hygiene contributes, calf diphtheria and infectious pneumonia must be mentioned. In all outbreaks proper attention must be given to isolation of affected animals and disinfection of premises and equipment.

POULTRY DISEASES

In no aspect of livestock husbandry is hygiene more important than in poultry farming, for the intensive methods which are frequently practised in which large numbers of birds are maintained in close proximity and under artificial conditions are particularly favourable to the spread of infectious disease.

The only diseases of poultry which are notifiable are those which are covered by the Fowl Pest Order of 1947 (Newcastle disease and fowl plague) but there are many other conditions which can, if un-checked, cause considerable devastation. Among the more important of these are infections caused by organisms of the salmonella group, *S. pullorum* (pullorum disease or bacillary white diarrhoea), *S. gallinarum* (fowl typhoid), *S. aertrycke (S. typhimurium), S. enteritidis* and *S. thompson;* the avian leucosis complex (fowl paralysis); infectious laryngo-tracheitis; coccidiosis; aspergillosis; tuberculosis; fowl pox; fowl cholera.

The general principles of hygiene for the control of disease on the poultry farm are the same as those necessary with other types of live-stock but some special problems are presented, as for instance in the case of infections such as B.W.D. which may be egg-borne.

The type of husbandry adopted is a most important factor in the control of disease; on free range, for instance, if large fixed houses are used there is considerable risk of heavy contamination of the

area immediately around the houses and small portable houses which can be moved regularly are to be preferred. The semi-intensive system where there are fixed houses with alternate runs, one of which is rested whilst the other is in use, can be satisfactory for a time if overcrowding is avoided but, in spite of the alternation of the runs, trouble frequently results from the land becoming fowl-sick with the development of conditions under which the spread of parasitic and other infections is favoured. This trouble can be overcome by the use of the folding system, where the fold units are moved on to fresh ground daily, provided that young stock are not folded over the same ground twice in a year as coccidial oöcysts can survive on the land for as long as twelve months under favourable conditions. The folding system has the additional advantage that the birds are kept in small groups and should an outbreak of disease occur, isolation is more readily accomplished than with other methods.

The intensive system aims at keeping the maximum number of birds in a limited area and nowadays this is usually done by confining the birds in individual battery cages or, more recently, by the deep litter system (page 268). Infectious diseases are uncommon with the laying battery system and it is claimed that when the deep litter system is established it is hygienic in its operation, provided that the surface of the litter is regularly stirred so as to keep it in a loose and absorbent condition and thus ensuring that fresh droppings are promptly absorbed and do not accumulate on the surface.

The movement of growing birds from one type of accommodation to another should never be carried out until the new accommodation has been cleansed and disinfected. This should be done in accordance with the general principles laid down on page 320, i.e., soak in disinfectant, scrape the walls and floor, cleanse with a hot 4 per cent. solution of washing soda, again soak in disinfectant and then leave to dry with the windows and doors open. For general usage a cresol disinfectant is probably most satisfactory but for the destruction of coccidia a 10 per cent. solution of ammonia must be employed. The fittings of poultry houses should always be constructed so that they can readily be removed for cleaning, and drinking vessels and food troughs particularly must be kept scrupulously clean at all times. Where external parasites are troublesome benzene hexachloride smoke generators or "candles" are most effective or the perches may be painted with a 40 per cent. solution of nicotine sulphate.

Owing to the great susceptibility of the newly hatched chick to salmonella infection the disinfection of incubators with the removal of all fluff and debris (a vacuum cleaner is useful for this purpose) is of considerable importance. The best procedure to adopt is that outlined

Ports should be left open and fumigation should continue for 20 minutes, after which the receptacle should be removed.

(iii) After all chicks have been removed from the hatcher and if possible before loose fittings, fluff and debris have been removed, the hatching compartment should be fumigated for 20-30 minutes with ports closed. (Using for maldehyde at the strength (B).)

(iv) As an alternative to fumigation, the hatcher, with the trays in position, may be sprayed with sodium hypochlorite solution or with an approved disinfectant (see para. 6 below) so that fluff and dust are saturated. A fine spray should be used.

(v) Hatching trays should be removed, thoroughly soaked in and then scrubbed with 4 per cent. solution of common washing soda or *sterilized by steam*. Other loose fittings should be similarly treated.

(vi) Hatching compartment and remaining fittings should be thoroughly cleansed and wiped down with sodium hypochlorite solution or an approved disinfectant, and dried.

5. *Incubators with combined setting and hatching compartments.*

(i) Empty incubators should be fumigated for at least 30 minutes with ventilators closed (using formaldehyde at strength (B)) before the commencement of the hatching season and at any time during the hatching season when a machine is empty.

(ii) In the case of such incubators or in those where for any other reason it is not practicable to carry out the routine described under 4 above because of the need to avoid fumigation during one or other of the two danger periods ((a) 24-84 hours after setting, (b) when there are newly hatched chicks in the machine) each batch of eggs, immediately before setting should be fumigated in a special air tight chamber in which "trayed" eggs can be placed or which is so arranged that the whole surface of the egg is exposed to the action of the formaldehyde gas. After each hatch, disinfection of the hatching trays and fittings and the floor of the machine should be carried out as in para. 4 (v) above.

(iii) If losses from salmonellosis continue in spite of fumigation at strength (B) the advice of the Ministry's Animal Health Division should be sought. This can be obtained on application to the nearest Animal Health Divisional Office or to the Provincial Poultry Advisory Officer or County Poultry Advisory Officer.

6. *Approved Disinfectant.*

An approved disinfectant is one which is sold in a container bearing a label indicating that, when diluted as prescribed on the label, it is approved by the Ministry as a disinfectant for the purposes of the Diseases of Animals Acts.

7. *Solution of Sodium Hypochlorite.*

A mixture prepared by adding 19 parts by volume of water to one part of a sodium hypochlorite solution containing 1 per cent. to 2 per cent. of available chlorine ; the mixture to be freshly prepared before use.

8. *Notes on Hygiene.*

The following precautions are detailed for the guidance of hatchery proprietors who should adopt them as routine measures.

(a) Cases and fittings used for the collection of hatching eggs should be disinfected with an approved disinfectant, or with a solution of sodium hypochlorite or should be placed in an airtight compartment and fumigated by the formalin method for at least 30 minutes.

(b) Assistants picking up chicks at hatching time should wear rubber or mackintosh aprons, and keep their sleeves rolled up to the elbow After each breeder's chicks are taken hands and aprons should be thoroughly washed with soap and water, preferably warm to which a small quantity of disinfectant has been added Aprons should be sponged with sodium hypochlorite solution or with another reliable disinfectant

(c) Hatching trays should be removed from the hatching room complete with debris and emptied into bins or other receptacles used for the purpose When their contents have been disposed of, they should be disinfected with a reliable disinfectant and stored in some isolated place

(d) Sexing should be undertaken in a room used for no other purpose Operators should wear rubber aprons, a pair of rubber or oilskin cuffs to the elbow (for use when sleeves are not rolled up) Itinerant sexers should, in addition, wear rubber boots and sexers employed mainly at one hatchery should wear rubber boots when working at premises other than their centre of employment Sexer's tables should be surfaced with metal or hard wood The trays into which the chicks are dropped should be made of metal or enamel ware with a layer of cotton wool in the bottom of each A wash hand basin is an essential fitment in every sexing room.

(e) Sexers should wash their hands before commencing work, and, when dealing with large numbers of chicks, on several occasions during the day

(f) Washing should be done with soap and water to which a small quantity of disinfectant has been added A nail brush should be used on nails and hands

(g) Cotton wool or other suitable material in chick trays should be renewed as frequently as possible but in any case must be renewed between each different breeder's chicks

(h) At the end of the day each sexer should disinfect his table, bowls, apron and cuffs Rubber boots should always be disinfected before proceeding to another hatchery or poultry farm.

(i) Every effort should be made to reduce the amount of dust in the hatching rooms to a minimum. Sweeping, whether of floors or machinery, should only be done after the surface has been damped with disinfectant After a hatch is taken off it is a good plan to spray the floor of the rooms immediately surrounding the machine with a disinfectant solution.

9, Control of Vermin

Rats and mice are carriers of certain bacteria which can induce disease in poultry It is, therefore, essential to ensure that the hatchery premises are, in the first place, cleared of all vermin and thereafter kept clear of them by any recognised method of extermination and prevention of entry

THE TRANSPORTATION OF LIVESTOCK

WHEN animals are transported from one place to another it is important, for humanitarian reasons, that they should be subjected to the minimum possible discomfort and, from the economic aspect, that they should reach their destination without deterioration in physique. Such transport may be merely a change of ownership or conveyance to slaughter or sales.

Movement within the United Kingdom is governed by the Transport of Animals Order of 1927 and amending Orders of 1931, 1939 and 1947, and The Transit of Horses Order of 1951. These Orders if properly observed will eliminate cruelty, but much more can be done to improve transit conditions and ensure delivery in a state equal to that pertaining when the animals are despatched. Reference is made below to the broad principles of these Orders but the actual Orders should be consulted on matters of detail.

In organising conveyance certain fundamentals should be kept in mind :—

(1) The degree of comfort required by an animal is relatively small when compared with the requirements of humans. It can usually be attained by a proper adherence to the needs of hygiene, nutrition and exercise required by an animal whether static or in transit.

(2) The shorter the time involved in transit, the better condition will the animal preserve for delivery. Consequently close attention to the route and method of transport should be observed.

(3) The transport of sick and pregnant animals is governed by the various Orders ; nevertheless livestock attendants should be fully aware of such animals in their keeping and pay close attention to them.

(4) Where possible, the transit of aged and fat animals should be avoided, particularly in the case of pigs.

(5) An all important factor is the season of the year at which animals are to be moved. Very hot or very cold, icy weather may induce mishaps.

(6) It will be the duty of the despatcher to provide adequate restraint or crating. This may prove to be the most important factor governing safe transit on a journey.

There are various methods of moving animals and they may be considered under the headings of : *Air, Rail, Sea, Road and Walking.*

Air. This mode of transport is still in an evolutionary stage and has been limited mainly to the transport of racehorses to and from the Continent It presents obvious features which recommend it for this purpose Chiefly, the time involved is short and the animal need not leave its training quarters till quite near the time of racing, and also the undesirable effects of prolonged travel and changed diet are in part eliminated There are, however, factors which may prevent the movement of animals by air The expense of chartering an aeroplane may justify itself in the case of a racehorse, but except in rare cases it will not be worth while for other animals

The noise and movement of flying leads to considerable excitement and demands a very close attention to restraint Nearly all accident cases reported so far are due to a breakaway whilst air-borne Undoubtedly the best method of restraint to adopt is to include the horse in a box, similar to a loading crate, adequately padded and strengthened and narrow enough to prevent him becoming cast The recommended measurements for such a crate are, length 9 ft by height 7 ft by width 4 ft Kapok padding can be used, covered with stout canvas The most important feature to be observed is minimum weight, with adequate strength.

No statutory regulations govern the transport of animals by air

Walking. This method of transporting animals exists to-day in only a very few places where other modes of transport are not available The shifting of great herds of beef cattle in North America, for instance, has been superseded by the railways, and only in parts of Australia, South Africa and Asia is it still usual to move them on the hoof The main factor to be observed is rate of travel This must allow the animals to keep condition and should permit adequate grazing and watering time

Rail Within the United Kingdom this is the most important method of transporting animals The Order of 1927 and its amendments are detailed and provide adequate protection for the livestock if properly observed

Except where an exemption is made specifically, all animals must be carried in covered trucks A ruling of this kind is not in operation on certain parts of the Continent and open trucks are common. It will readily be appreciated that inclemency of the weather may produce dire results if inadequate protection is given

That animals shall have a good foothold to prevent casting, slipping and other such causes of injury is obvious Therefore the trucks must

have spring buffers and the floors be fitted with battens for the carriage of cattle or, with other species, be well littered with straw or sand. The battens are placed across the floor of the vehicle except in the doorways where they should be placed lengthways. All bolt-heads and other projections must be covered or removed to prevent injury. There must be an inspection opening at floor level since it is not always desirable to disturb animals by opening or lowering the doors. Trucks must be constructed so that they can be cleansed and disinfected adequately.

All bulls whether polled or horned must be secured by the head or neck, and all horned stock carried in the same truck as a bull, should be similarly tied.

Sick or injured animals must not be carried nor must a cow that is reasonably expected to calve during the period of transit. Calves, sheep, goats and swine, if carried in the same truck as cattle or horses, must be separated from them by partitions. Other species will often aggravate the temper of an animal, particularly in the case of male animals.

Overcrowding will not of course be permitted by the intelligent livestock attendant. The risk of injury and discomfort caused by this needs no enlargement.

Between November and April, sheep shorn within a period of less than sixty days prior to transit must not be carried unless there is adequate protection on the trucks by means of tarpaulins. These should not interfere with ventilation.

A most important feature, that must never be overlooked, is the watering of animals during transit. The Orders state that cattle and pigs must be watered at least once in 24 hours and sheep at least once in 36 hours. Every station reasonably expecting consignments of animals to pass through must, by law, have adequate supplies of water and food available.*

Generally speaking the regulations apply similarly to horses, but there are some additional points set forth in the Transit of Horses Order of 1951. Horses must be protected from the weather, and during the months of October to March inclusive, horses carried in trucks which are open at the sides must be protected by tarpaulins. Particular attention must be paid to facilities for loading and unloading. Horses must be fed and watered at intervals of not more than 12 hours. In view of the long periods which may ensue when travelling by rail, forethought must be exercised with regard to the provision of food at stopping places.

* See Section 22 of the Diseases of Animals Act, 1950.

For long journeys with stallions or other animals which may exhibit vicious tendencies, the livestock attendant should exercise great care in determining whether or not to place two animals in a box together, and more particularly he should study individual temperaments when pairing

Sea Transport. As sea transport often involves long journeys, with the possibility of a rough passage, certain important details must receive attention The transit of horses by sea is governed by the Exportation and Transit of Horses, Asses and Mules Order of 1921 and a number of amendments Other animals are protected by the Transit of Animals Order of 1927 in so far as coastwise journeys and journeys between ports in Great Britain, Ireland, the Channel Islands and the Isle of Man are concerned and by the Animals (Sea Transport) Order of 1930 on ocean going vessels

The Orders make detailed provision for the size and type of accommodation, ventilation and lighting ; they prescribe which parts of the vessel may be used for carrying animals and specify which types of stock must be secured by head ropes (bulls, horned cattle, fat cows and heifers, pregnant cattle and milk cows) Mixed consignments must be divided into various classes and separately penned Provision must be made for food and water if the journey is to take more than eighteen hours

A number of important practical points are as follows —

(1) If piped water is not available then the animals must be so housed that bucket handling does not mean traversing the crew and passenger quarters

(2) If the animals are between decks, the drainage scuppers or other method of removing excreta must be carefully watched. The air becomes extremely humid and may lead to a foul, ammoniated atmosphere later The animals' resistance will already be lowered by transit and there will be a further predisposition to the diseases peculiar to transport if the environmental conditions are bad

(3) Crated animals must be examined as a routine every two or three hours Pigs in particular will lie so that a leg protrudes This may become cramped and swell and it may only be possible to move it by sawing away the offending portion of the crate

(4) If space is available the animals should be exercised, or allowed a period of freedom, each day

(5) An approved killing instrument must be carried discharging a captive bolt or a bullet. The latter is to be discouraged especially between decks since the risk of ricochet is very great

Injured animals must be slaughtered but their carcases and those

of animals which have died from disease or other causes must not be · cast overboard within the 3 mile limit.

(6) There should always be some empty reserve pens for such animals as it may seem desirable to segregate during the voyage.

Much of the work in regard to the transport of equines has been effected by the Royal Army Veterinary Corps and this authority perfected the method of net-loading. The animal is walked on to a net which is drawn around it by a crane. When clear of the ground the legs protrude and the animals are swung aboard. There is little risk of accident if the crane man is experienced.

The army will allow donkeys and mules free movement in the holds if each is provided with a halter, the lead line being coiled at one side of the head. This allows them to be caught when required, it being. unreasonable to expect handlers to move among tightly packed mules in order to catch them.

Pigs are usually transported in pens. Each pen consists of a rectangular box, having a hatch entrance at one or both ends. A fixed trough is provided at the head end. The crates are usually made of wooden slats, approximate measurements being 2 ft. 6 ins. wide, 3 ft. high and 5 ft. long. It may be found that a standard crate gives too much or insufficient room for a pig on a long voyage. Either fault is dangerous, the former because animals may become cast in a position from which they cannot extricate themselves, the latter because it leads to cramp. The crate should be modified accordingly or one of the correct size obtained.

Road Transport. Whenever possible road transport should be carried out in a properly constructed horse-box or cattle truck. Sometimes, however, the vehicle used will be an ordinary truck which has been adapted to comply with the regulations. A record giving details of journeys, the animals carried and the disinfection of the vehicles must be kept.

Transport to markets or shows is achieved in a cattle truck, this being merely a large box in which the animal is tethered. The floor must be fitted with battens or straw covered. There must be no projecting objects which might cause injury and the back must be made so that it drops to become a loading or unloading ramp. A common cause of accidents arising is a rotten or weak floor ; sprains, strained tendons or ligaments and broken legs may ensure when a beast's foot goes through the floor and the beast struggles free. The regulations require that the truck shall be easily and properly disinfected after each consignment of animals. The vehicle must be so constructed that a protective roof or adequate covering can be provided in bad weather

and there must be means of inspecting the interior at a height of not more than 4 ft 6 ins from the ground   When two or more horses are carried, the vehicle must have facilities for erecting a movable partition, not less than 4 ft 6 ins high ,across it

Heavy draught horses must always be placed so that they face either the front or the rear and no more than three heavy draught horses may be carried abreast   If the vehicle is large enough a second group of three may be carried behind the first provided the two groups are separated by a partition   Proper precautions must be taken in all cases to ensure that horses are not thrown about by the movement of the vehicle, but overcrowding must be avoided   Horses facing the front or rear must always be tied by a light head rope   Different categories of horses must not be carried in the same vehicle unless adequately separated   Food and water must be supplied at intervals of not more than 12 hours

The construction of special mechanically propelled boxes for thoroughbred and other horses started in 1912 , to-day the largest models may carry up to six horses   They are equipped with an attendant's room at the back, telephone to driver's cab, electric lights, air standardising equipment and heating apparatus   Horse ambulances with winches for raising a horse that is down are also constructed but an entirely satisfactory type has not been devised   Some are constructed with a side loading ramp and some with a rear ramp   Special boxes are constructed for the tropics

Cleansing and Disinfection of Vehicles.   In each case where there are statutory regulations governing the transportation of livestock, provision is made for the compulsory cleansing and disinfection of the vehicle as soon as practicable after each consignment   The process of cleansing and disinfection involves —

(i) scraping and sweeping of the floor, roof and sides of the inside of the vehicle, and the sides and ends of the outside, and all parts of the vehicle with which any animal or its droppings have come in contact , scrapings and sweepings, and all dung, litter, etc , must be well mixed with quicklime and effectually removed from contact with animals, or destroyed by fire , then

(ii) thorough washing, scrubbing or scouring with water of the same parts of the vehicle , and then

(iii) thorough coating or washing with an approved disinfectant   Crates, ropes, loading boards, etc , must also be thoroughly cleansed and then coated, washed or saturated with an approved disinfectant.

As far as ships are concerned, all parts of the vessel with which any animal or its droppings have come in contact must be similarly cleansed and disinfected.

Transportation of Poultry.   The Conveyance of Live Poultry Order of 1919 makes provision for the protection of poultry during conveyance by water, rail or road.   The main requirements of this Order are as follows :—all poultry must be protected from exposure to bad weather or excessive heat ; and must be carried in properly ventilated receptacles ; the vehicle or parts of the vessel used must also be sufficiently ventilated ; crates must be secured so as to stop shifting during transit, and the birds must not be overcrowded ; birds must not be unnecessarily tied by the legs or unnecessarily carried head downwards ; receptacles must be suitable for the purpose and must be constructed so as to protect the poultry from injury by protrusion of the head, legs or wings ; receptacles containing poultry must be handled with care ; turkeys, geese and ducks, when conveyed by rail or sea, must not be in the same receptacle as other poultry unless they are in separate compartments ; food and water must be provided by the master of the vessel or the railway company, as the case may be, if the journey is protracted by exceptional causes.

The cleansing and disinfection of receptacles used for conveying poultry are prescribed under the Poultry Markets and Receptacles (Disinfection) Order of 1936 (see page 422).

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